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First Edition

VOLUME II

Report of the Transactions
of the
American Academy of Optometry

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REPORT OF THE TRANSACTIONS

of the

SIXTH ANNUAL MEETING

of the

AMERICAN ACADEMY OF OPTOMETRY

Held at
New York City
December 4th, 5th and 6th,
1927

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PROGRAM OF THE SIXTH ANNUAL CONVENTION OF THE AMERICAN ACADEMY OF OPTOMETRY

Columbia University and Hotel Pennsylvania
New York City

December 4th, 1927

2:30 P. M.	*Chairman's Address* - -	Dr. E. G. Wiseman, Buffalo, New York
3:00 P. M.	*Secretary-Treasurer's Report* -	Dr. C. E Cox, Rochester, N. Y.
8:00 P. M.	*Muscle Anatomy and Physiology* -	Prof. F. A. Woll, New York, N. Y.
9:00 P. M.	*The Evolution of the Human Eye* -	Prof. F. A. Woll, New York, N. Y.

December 5th, 1927

10:00 A. M.	*General Procedure in Handling Kratometer Cases* -	Dr. O. L. McCulloch, Holyoke, Mass.
12:15	Luncheon	
2:30 P. M.	*Complacency* - - -	Dr. R. B. Raup, New York, N. Y.
3:30 P. M.	*Ancient and Modern Theories of Light* -	Prof. J. P. C. Southall, New York, N. Y.
4:30 P. M.	*Display of Models and Specimens of the Eye and Nervous System*	
7:00 P, M.	Formal Round Table Dinner - -	Dr. E. G. Wiseman, Buffalo, N. Y.
10:00 P. M.	Business Session and Election of Officers	

December 6th, 1927

9:00 A. M.	*Visual Nerve Tracts* -	Dr. R. M. Peckham, Waterbury, Conn.
10:00 A. M.	*The Control of Myopia by Reverse Stereoscope* -	Dr. E. LeRoy Ryer, New York City
12:00 P. M.	Luncheon	
2:00 P. M.	*The Evolution of the Visual Apparatus* -	Dr. E. G. Wiseman, Buffalo, N. Y.

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OFFICERS

Chairman - - - - - -	Dr. Eugene G. Wiseman, Buffalo, N. Y.
Vice-Chairman - - - -	Dr. B. Woodward Hazel, Baltimore, Md.
Secretary - - - - - -	Dr. Charles E. Cox, Rochester, N. Y.

MEMBERS OF EXECUTIVE COUNCIL

Dr. E. G. Wiseman, Chairman - - - - -	Buffalo, N. Y.
Dr. B. W. Hazel - - - - - - - - - - -	Baltimore, Md.
Dr. M. Steinfield - - - - - - - - - -	Paducah, Ky.
Dr. E. Petry - - - - - - - - - - - -	Rochester, N. Y.
Dr. C. C. Koch - - - - - - - - - - -	Minneapolis, Minn.
Dr. W. H. Hammond - - - - - - - - -	Lockport, N. Y.

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REPORT OF THE TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

The sixth annual meeting of the American Academy of Optometry convened at the Hotel Pennsylvania, New York City, on December 4th, 1927, the Chairman, Dr. E. G. Wiseman, occupying the chair.

ANNUAL ADDRESS OF THE CHAIRMAN

E. G. Wiseman, Opt. D., F. A. A. O.
Buffalo, N. Y.

The American Academy of Optometry was formed in 1921 by a small group of mid-western optometrists who had become dissatisfied with the lack of an organization composed of practitioners actuated by a desire for higher ideals and more advanced scientific work.

Naturally, very slow progress was made in the first few years of its existence because there seemed to be too few who combined with the realization of the need of such a group the belief that it could be satisfactorily effected and the willingness actively to engage in the necessary pioneer work.

It was considered unwise to take too seriously the sporadic expressions of desire for such an organization and to force its growth with them as the basis for justification because too often in the past somewhat similar ambitions have been voiced and heeded, with the result that a vast amount of work had been done with no lasting benefit. Rather, real damage has been done because many started idealistic movements of one kind or another and were sadly disillusioned by the mass of inertia and indifference they encountered. In this case we preferred to "sit tight" and wait until the demand became unmistakable.

With the passage of time the qualities mentioned have gradually been awakened. The past year especially has witnessed the rapid growth of an insistent demand that we have an organization which will adequately represent the highest aspects of optometric science and practice and form the vehicle which will help us to travel still farther and faster in the direction toward which so many of us be-

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lieve optometry is progressing. Instead of silently wishing, the professional spirit in this respect is fast becoming exceedingly articulate.

Some of us believe that the Academy is amply capable of fulfilling all functions which may be desired. It is true that the basic requirements of the Academy, for details of which you are referred to the Chairman's 1926 address[1], prevent its growth to large proportions for a number of years but, on the other hand, it will most decidedly be composed of an exceptionally high percentage of the very best practitioners in the country. These men are genuinely in earnest in their desire to promote our highest ideals with regard both to externals, such as manners and methods of projecting optometry upon the public mind, and to the development and dissemination of scientific research.

Of course the Academy idea meets with bitter opposition here and there. Some even question the moral right of a group of similarly-minded men formally to organize such an institution as ours and place any restrictions upon the membership. They would have it open to all. There would be no point in creating a body on that basis for it would soon degenerate into a politico-debating society. We have too many examples of the kind to want to emulate or duplicate them.

As now constituted, there are many excellent men prohibited from joining, and some perhaps may obtain entrance who will not be as desirable as could be wished but at least we have some control over this and can rest assured that the average will be high and that the probability of disturbing elements entering our deliberations will be as small as can reasonably be hoped.

It is expected that the American Academy of Optometry will constitute essentially a study group and a mutually helpful group, and that it will gladly pass on the results of its investigations to the entire optometric profession. Up to date we have been unable to engage in any scientific work, other than through papers and discussions such as will be presented here today, but as we become stronger our funds for such purposes will be sufficiently augmented to permit this.

To facilitate progress in this particular, your chairman recommends the appointment of two special committees—Membership and Scientific. The duty of the first should be to seek out those practitioners who constitute available material for Academy membership, investigate their methods and qualifications and submit to the Executive Council the names of those whom they find will fulfill our requirements.

The duty of the second shall be to determine the specific research upon which the organization should engage and to carry out this work as far as our funds will permit.

There has also been appointed a Policy Committee which is to pass upon the publicity and location of the small town practitioner

[1] The American Academy of Optometry, Vol. 1.

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and such other delicate points as may arise but regarding which it would be unwise to lay down hard and fast rules.

There should also be a Program Committee, co-operating with the Scientific Committee, for the purpose of formulating the program of the meeting months in advance.

The future of the Academy depends entirely upon the individual members. They must show interest and make strong efforts to attend the meetings. They should be willing to contribute well-prepared papers at any meeting after having received due notification. They can assist very vitally in growth of membership, which will control our efforts at scientific research, by recommending for invitation those whom they know positively can meet the requirements.

Dr. Charles E. Cox, the Secretary-Treasurer of the American Academy, was then called upon to give his report. This revealed that twenty-three optometrists had been awarded fellowship during the past year and that on this date there was a balance of one thousand thirty-nine dollars ($1,039), in the treasury. This concluded the afternoon session.

The American Academy of Optometry reconvened at eight o'clock, the Chairman, Dr. E. G. Wiseman, occupying the chair. Dr. Wiseman introduced Professor Fredrick A. Woll, of the Optometry School of Columbia University.

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MUSCLE ANATOMY AND PHYSIOLOGY

Fredrick A. Woll, Ph.D.
New York, N. Y.

Dr. Woll started his lecture by making the statement that "I will address you this evening as an Anatomist and not as an Optometrist. I do this because I do not want to be prejudiced. One of the tasks we, as teachers have, is to train students to think, and the manner in which I will present my topic tonight is, in a measure, based on the pedagogical theory that if the listeners can be made to think while absorbing a lecture, then a more lasting impression and more satisfying effect can be created. Thus, I shall try to make you think."

Dr. Woll then brought out the fact that there are three kinds of muscles: voluntary, involuntary and cardiac. He made a cross-sectional drawing of a voluntary muscle and called attention to the distribution of muscle fiber. He showed how the fibers are grouped, and how each fiber is enclosed in a sheath; this sheath is called sarcolemma. The sheathed muscle cells are held together by a connective tissue called endomysium, and a group of such connected muscle cells are enclosed in another sheath of connective tissue called epimysium. Such enclosed groups of muscle cells are enclosed in a membranous sheath called perimysium.

With this complex structure laid before his audience, Dr. Woll reverted to the discussion of the muscle fiber, or as he preferred to call it, the muscle cell. He brought out the fact that every muscle cell is a complete chemical laboratory in itself.

In discussing the physiologic requirements of a cell, Dr. Woll clearly established the fact that the chemical elements required to keep the cell in good condition were as variable in formula as there are kinds of cells. In other words, that each cell required a different combination of chemical elements to keep it in good physiological and anatomical condition.

Dr. Woll then said that a cell has the power to contract but never relaxes completely. It contracts to varying degrees but does not relax completely except when it is dead. The following are a few of the important points emphasized by Dr. Woll:

"An important physiologic requirement is rest. The more a cell acts in its contractings, the more it must rest. Rest periods are, in many instances, only a pause."

"A heart with a heart beat of 70 times a minute will in twenty-four hours do enough work to lift one pound several hundred thousand feet."

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"In all of the muscles of the body, it will be found that the mount of work which might be represented by the acts of contracting is especially great, but in contrast to this, the result is comparatively disappointing when compared with the energy expended."

"When an individual is round shouldered or has some other form of posture abnormality, he sometimes goes to a specialist who prescribes exercise. This specialist depends on fundamental practices born by the results from experience."

Dr. Woll then took up the topic of muscle action and divided this topic into three subheadings: First, concentric contraction; second, static contraction, and third, eccentric contraction. A concentric contraction is a contraction in which the muscle relaxation or contraction is due to the increase or decrease of the fluid received by the cell. Muscle contraction is a shortening of a muscle fiber.

Static contraction is that form of muscle contraction by virtue of which the muscle contraction stops at a given point. A complete static contraction is the fullest contraction of which a muscle is capable and then held. Eccentric contraction is that state of muscle contraction in which a muscle is contracting in an endeavor to hold a load that is beyond its power with the result that the muscle will be in a state of contracting though lengthening because of an overload which it is trying to overcome. In muscle action, we always have the protagonistic and antagonistic muscle arrangement so that there is always a combat in every muscle action. The conquering muscle determines the result of muscle action. When protagonistic and antagonistic act equally, there is a state of stability.

Dr. Woll then pointed out that there were three phases during muscle action: First, electric—the impulse sent to start the muscle going; second, thermal—the heat created due to the chemical action in the muscle being used; third—mechanical—the action that is produced, the response or, what the psychologists call, the response to the stimulus.

Dr. Woll then said that the specialist who treats posture knows that there is muscle inertia. He, therefore, causes concentric contraction of the apparently faulty muscle. His principal difficulty lies in the isolating of muscles, but he usually finds it necessary to exercise muscles in groups. If you exercise a muscle to an extreme, you must hold the muscle in its state of extreme concentric contraction. The antagonist must not be exercised when the protagonist is to be strengthened because the antagonist does not need the exercise. An important point to be borne in mind is that exercise represents the use of the muscles and that rest periods must be in proper proportion.

The following is, he claimed, another point to be borne in mind in muscle exercise. If there is good physiologic functioning, then exercise by virtue of its increased demand increases the functioning of a muscle with the end result of further structural development. The suddenness of a physiologic demand will be met by as sudden a physiologic supply. It should be apparent to all that the study of

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general anatomy and physiology is as fundamentally important to an Optometrist as any of his basic optical or optometrical subjects. By producing the maximum of contraction in the protagonistic with a minimum of contraction in the antagonistic muscles, the best results can be produced, and, for the best results in "muscle correction" the muscle to be corrected, or improved, should be held in a complete concentric static condition. That will aid in the correction because a muscle has a tendency to hold the position in which it was last used. Disorder is the result of overwork. Rest brings about physiological order.

In summing up, Dr. Woll presented the following as the results of muscle exercise: First—an immediate, transient and local increase in the blood supply of the muscle. Second—An immediate, transient and local increase in the lymphatic and venous drainage of the muscle, Third—An immediate and transient increase in the heart rate, blood pressure and rate of respiration (vital function). Fourth—An immediate and transient increase in the superficial circulation of surrounding parts. Fifth—A later, more lasting increase in the size, strength and functional endurance of the exercised muscle, (a part of tonicity). Sixth—A later, more lasting decrease in the length of the exercised muscle (another part of tonicity). Seventh—A later, more lasting increase in the size and strength of the tendons, ligaments, sheaths, bones and joints directly associated in exercise (more of tonicity). Eighth—A later, more lasting increase in the size and efficiency of the nerve cells in the exercised motor centers. Ninth—An improvement and perfection of old neuro-muscular co-ordination. Tenth—The establishment of new neuro-muscular co-ordination with the possibility of developing new paths for the efferent and afferent nerve impulses. Eleventh—An improvement in the blood and lymph circulation (special or general). Twelfth—A perfection of existing neuro-muscle co-ordinations. Thirteenth—An increase in general catabolic activity. Fourteenth—An increase in circulation of the products of chemical activity of all tissues and organs associated directly and indirectly in the exercise. Fifteenth—An increase in the desire for rest after the exercise, and a desire for complete rest—sleep. Sixteenth—An increase in the anabolic activities of all of the tissues concerned directly and indirectly with, therefore, a general, structural and functional benefit. Seventeenth—A gain in weight or increase growth (or both), continuing until metabolic equilibrium is re-established. Eighteenth—A perfection of the physiologic efficiency of the orgna. Nineteenth—A better development of the potential powers.

Each one of these nineteen subdivisions is an integral part of tonicity, or in other words, the production thereof or the bringing about of the potentiality of a muscle.

Tonicity is a readiness in the electrical or chemical phase to activate or motivate in terms of physiological readiness and preparedness. Tonicity may, therefore, be said to be an active alertness, or a willingness to spring into action, arrived at only by actual use.

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DISCUSSION. Dr. E. E. Hotaling asked if it is unusual that we find a defective rectus muscle, that is to say, one that is slow in its response?

Dr. F. A. Woll answered this by saying that if the muscle is in its place, the impulse is the element we are concerned in, in this type of case. When recti muscles need exercise, it would also indicate that the entire system would need exercise, which must naturally include an element of play for the best results to be obtained.

Dr. E. G. Wiseman said that in doing kratometric work, we often find a neuro-muscular status that is abnormal. A prism is then prescribed for constant wear. The abduction does not change. We then give more prism for constant wear and the abduction continues as before. What then is the anatomic status of these exterior recti muscles?

Dr. F. A. Woll thought that whenever we prevent a tissue or organ from working that its anatomy and physiology deteriorates. We must work these muscles; not give them less to do, if we want them to be active, healthy and well functioning.

Dr. E. G. Wiseman said that his conception of muscular action was that it developed muscular tissue.

Dr. F. A. Woll agreed, saying that a muscle that has little or nothing to do will loose in both size and power to function. He added that Dr. R. M. Peckham was correct in advocating general exercise in those ocular cases suffering from muscular insufficiencies.

Dr. H. R. Higley inquired as to the possibility of mental conditions having anything to do with faulty muscular response.

Dr. F. A. Woll agreed, saying that he preferred however to refer to these cases as nervous rather than mental, feeling as he does that much of this type of disorder is brought about by a lack of physical exercise.

Dr. B. W. Hazell then referred to the nineteen subdivided results of muscular exercise asking if those subdivisions referred to voluntary muscles only.

Dr. F. A. Woll answered this in the negative saying that these results applied to all muscular tissue.

Following this short discussion Dr. Woll then presented his second lecture.

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THE EVOLUTION OF THE HUMAN EYE

Fredrick A. Woll, Ph.D.
New York, N. Y.

Dr. F. A. Woll introduced this subject by asking the question "Why do we have eyes?" The most feasible answer to this, he said, is that nature always meets a demand. In the early development of animal life there was no need for sight, and until animal life had been developed to a point where sight was necessary, nature did not provide any means for this function. He showed how, when unicellular bodies were created, their entire body had a part in every function which they were capable of exercising. There were no individual organs in these unicellular bodies to meet the demands of eating, drinking, digestion, excretion, feeling, etc., but that every part of the unicellular body was so constituted as to make it capable in its limited way of exercising these functions.

The next creative step came when these unicellular bodies developed the function of motion, and since animals usually proceed in the direction of the long axis of their body, the forward end experienced a greater demand upon it than did any other part of the body. Nature stepped in at this stage of the development and provided a more sensitized condition at the forward end than at any other part of the body. The head end, therefore, became the part that interpreted the greater portion of the stimuli received by these animals. By virtue of this condition, and through the experience of practice, differentiation of tissues developed. The fact that survival was possible only for those who developed differentiation and alertness aided the evolution. Among the various stimuli received by these primitive forms of animal life was that of light. Light struck the head end and the interpreting ability of heat, rather than that of light-influence, was developed.

The next development provided by nature was the creation of that set of animals having eye spots. These spots cannot be considered in the same way in which we consider the eye today. The eye spots are sensitive to the heat element in light. "Heat has always been a valuable stimulation," said the speaker, "and the skin cells, which have been called eye spots, were for the purpose of interpreting the differences in the degree of heat stimulus." This might be said to be the first stage of the development of the eye, and it may be further said that the eye developed as the result of there having been light. Exposure of the skin to the sun develops pigment, and these eye spots can be generally said to be nothing more than slightly pigmented areas with nerve contacts.

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The chiton seems to be among the animals, which exhibited the first eye spots, but as has been said before, this eye was nothing more than a slight saucerlike depression in the skin, slightly pigmented and which made possible light intepretation in terms of heat.

The solen was the next step in the development of the eye, and in this case the depression is slightly cupped, more pigmented, but again its interpretive function is limited to that of the differentiation between degrees of heat.

Next came the limpet, a sort of shell fish. Here the eye spot represented a deeper cupped eye than that of the solen, and still more heavily pigmented. An interesting fact in the development of these eye spots is the fact that as nature provided them in larger and more sensitive form, the number of spots per animal was reduced.

The animal representing the next development of these spots is the nautilus. The cupping in the case of the eye of the nautilus is more spheric than in the preceding examples, and represents a spheric cavity with a pinhole opening, thus forming a veritable camera obscura. The cavity was filled with sea water and the nerve connection is the first indication of what might be called the development of the optic nerve and retina and rudimentary choroid. Here also is first found the ability to interpret light as such and not merely in terms of its heat element as in the lower forms.

All eyes up to this point in the evolutionary process are skin spots. The first real eye, as we consider them today, are those of the snail, there being two, one at the end of each eye stalk representing at first glance somewhat the appearance of a round headed pin. In all of the stages of development, there has been a gradual increasing of pigment, and the eye of the snail is the first that has a definite transparent front covering or cornea. The hollow cavity in this case is filled with a substance akin to the vitreous of the human eye. The pigmented layer has developed to what might be called a retina, and there is also a deeper layer resembling the choroid. The nerve is composed of a bundle of fibers and is, in appearance, the equivalent of the optic nerve of the human eye.

Next came the eye of the squid, in which we find the first indication of a crystalline lens and iris. Experimentation has also proved that this eye has no distant vision, but like the eye of the snail, has a cornea, vitreous, retina, choroid and optic nerve. This eye has developed after having passed through all of the previously recorded stages and represents the highest development in invertebrates.

At this point, the speaker made the statement that the embryonic stage is the important stage of the consideration of the development of the eye, and thus the development of the eye of the squid can be noted as passing through all of the elementary stages spoken of previously by the speaker.

As the egg of the squid is taken under observation during incubation, each step can be observed. First the slight pigmented spot, then the gradual increasing in cupping and pigmentation, and finally

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the complete eye which very closely resembles, in structure, that of the human being.

The principal difference between the eyes of this stage of development and that of the human eye, is the lack of an optic nerve head. The reason for this is that each nerve fiber from the rods and cones leaves posteriorly. From this form of structure, it can be readily seen that these eyes have neither blind spots nor yellow spots and that there cannot exist any form of central vision or fusion. The most sensitive spot, however, is probably over the nerve head, and there seems to be some rudimentary color vision.

The speaker than asked, "When and how did the vertebrate eye develop?" He answered this by saying, "Somewhere between the developmental stages of the skin cell, there must have been found the need for the creation of a vertebrate eye, but where this occurred, no one knows."

The vertebrate eye is formed by an extension of nerve tissue to meet invagination of skin. The physiological irritation from this contact causes a thickening of the tissue which indents and forms the eye. The retina of this eye is no longer transformed skin, but is now an extension of the brain. It has been determined that vertebrate animals have greater color perception and discrimination than do the invertebrates. This may be party due to color addition, experience or knowledge, as this may be applied to our central field. Our peripheral color sense is limited to an interpretation of shades of grey.

The lower animals have but one function for eyes—seeing laterally. Opposite sides are, however, joined in the cerebellum, and protective responses are manifested in the muscles of the side opposite to that being stimulated by light.

It is noted in the evolutionary process of the development of the eye that increased refinement in structure and function are provided as the demands continue to grow, but that nature will not be hurried and that the requirment seems at present to be a little in advance of the development in many cases. The chiasm, single binocular vision and better accommodative facilities are examples of this process of development. It may well be said that the requirements on all of our ocular functions as they exist today could not be made by the eyes of those who lived a few hundred years ago.

Dr. Woll urged optometrists to lay aside the consideration of the eye as a single unit and apart from all other parts of the body, but to take into consideration in their diagnosis that the eye is a part of the body and the condition of the body has its effect on the eyes.

Under the heading of comparative ocular anatomy, Dr. Woll brought out a number of interesting facts, and as an example, cited the eyes of a spider which are in reality, multiple eyes—a central eye surrounded by peripheral eyes, the peripheral eyes supplying the function of sentinel to give the alarm of approaching objects and the central eye as an analytical element.

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Carrying this subject further along, he emphasized the fact that in dogs, cats and animals of these types, the lids are fused until some time after birth until the interior structural detail is completed. In humans, babies keep their eye-lids closed for some time after birth for the same reason.

In the insects, all the individual eye requirement is grouped into a single group or multiple eye, the multiple eye being composed of from 2,000 to 50,000 sectors, conical or pyramidal in form, with their bases exposed, the sectors being joined together so as to make a solid, clear hemisphere with a faceted surface. The apexes of these sectors point toward the center where a ganglion is found joined to what is the equivalent of the optic nerve. This ganglion is covered with pigmented layer resembling a retina.

Along with the evolution of the mechanical parts and the receiving and interpreting portions of the eye, it became necessary to develop a receiving and sending station in the brain. As may well be said, we have the power of looking, seeing and understanding. All of these individual acts are the functions of or contributed to by the eye—the most perfect organ extent.

Following Dr. Woll's lecture, an informal business meeting was held, at which time Dr. E. G. Wiseman discussed the requirements for admission to the Academy. The report of the Rules Committee by Dr. J. H. Drakeford was read, but action was deferred. The various phases of membership requirement were discussed. The underlying purpose which caused the Academy to be organized was presented, and the aims and object to be striven for were laid before the meeting by Dr. E. L. Ryer, Dr. H. C. Doane, Dr. E. Petry, Dr. C. E. Cox and others. This concluded the evening session.

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REPORT OF THE TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

Monday, December 5th, 1927, the American Academy of Optometry reconvened in the lecture room of the Physics Building of Columbia University, the Chairman, Dr. E. G. Wiseman, occupying the chair. Dr. Wiseman introduced Dr. Oscar L. McCulloch.

GENERAL PROCEDURE IN HANDLING KRATOMETER CASES

Oscar L. McCulloch, Opt. D., F. A. A. O.
Holyoke, Mass.

It has been my experience that there is a variation between the results of a phoria test as obtained by means of the rotary prism, loose prisms employed with a trial frame and what I believe to be the better method as obtained by the use of the prism bars of the Kratometer. With this arrangement there is very slight chance of error as the prisms are held in position before the eyes as they should be and also they are considerably nearer the eyes than with most other methods. For really fine, scientific work along this line, it seems that there is little excuse for our taking phoria tests in any other manner. If we are easily satisfied with the old slipshod methods then we can use the Maddox Rod instead of the Savage method. This sort of a phoria test was intended to be taken under atropine, and being invented by and used by ophthalmologists, it has a proper place in their method of examining eyes, but for an optometrist to use it seems both awkward as well as inaccurate, especially when the Savage method is so simple of application. I think the only exception to this might be in the taking of the vertical phorias. These can be taken with a Maddox Rod fairly accurately as the convergence is less likely to affect the findings.

Before any ductions are taken it is well to study the fusion sense in detail. It is time well expended in doing this. The Kratometer offers an almost ideal instrument with which to study this function. The method which I follow as a routine is to set the instrument at the proper pupillary distance for near point with the septum in place, farther from the patient's face with wide pupillary distances and nearer with narrow ones. Then place the prism bars with their bases **out,** ten degrees (10Δ) before each eye. Ask the patient to then place his chin upon the chin rest and adjust the instrument until he is comfortably placed and is looking through the apertures slightly

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downward at the card upon the reading rod in front. All of this time he has had nothing of a definite nature to look at. I then ask the patient to close the eyes for a moment and upon opening them immediately ask him to describe what is seen. In this way I have given him no hint as to what he may expect to see so, therefore, the answers should be trustworthy. The card to be used first is the No. 3 or F-L card devised by Peckham. If normal, one should see an E with the normal amount of prism (20Δ) base out. If there is a tendency for the patient to say that first he sees E, then F, then L, and it sometimes changes so fast that he cannot state the changes because they are so rapid, then it is evident that there is imperfect fusion. There are patients who will only see one letter at a time, either F or L, but never the two simultaneously. These people have an alteration of vision between the two eyes and unless they were examined by means of the Kratometer it would probably never be ascertained. It is but one of the various forms of suppression, suspension or suspenopsia. There are scarcely two alike, but they all present the same general phenomena, the constant changing of the position of the letters.

Also there is the type of case which sees the F-L separated vertically. Sometimes this is described as merely an imperfect joining of the F-L to form E and then again it is plainly visible to the patient. Of course, this at once suggests a hyperphoria and a note should be made to investigate it at some later period in the examination. So you see there are many things to be found out from this simple test. It only depends upon the keen observation of the examiner to find many of these apparently obscure conditions. It is just these things which in the aggregate either spell the success of the refractionist or his failure.

In taking the abduction at distance a fairly large colored picture such as the cover of a Saturday Evening Post or anything which will retain the patient's attention seems to me to be the best test object. As before, adjust the pupillary distance correctly and remove the card holder from the instrument or at least lower the rod as far as possible and turn down the card holder so that it won't be in the line of vision of the patient. Place the distance correction of the patient in the cells of Kratometer next to the patient's eyes and place prism bars in position at zero base in. Now direct the patient's attention to the object at infinity and ask to be informed when the object starts to blur. If this happens within a few prism diopters then it indicates that the connection between accommodation and convergence is quite loose and if the patient be esophoric, it will not be an extremely hard task to break it down. This is especially true if from the blur point on to breaking point or diplopia is considerable. After having ascertained the point of blur and point of diplopia then the next thing is to find the point at which the patient can recover a single image. This is very important. If it be below the point of blur then the patient is surely a candidate for base in Kratometer training, both to build the amount of abduction and the

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ability to handle it flexibly. Also the point of recovery is the pivot from which is determined the amount of prism to be prescribed in the case of an esophore.

The abduction at the near point is taken in the same general manner as that at distance with these exceptions. The pupillary distance is narrowed to that of the near point and the object used is the familiar checkerboard of Peckham. Naturally the near-point correction is used and this applies even if the patient is not an actual presbyope. I use the correction I have previously obtained by the use of the cross cylinders at this point. Again the point of blur is obtained as the prism bars are increased in power.

Also the point of diplopia is found as well as the point of recovery of the single image. These are all important because upon their proper interpretation is determined the course of treatment you are going to pursue for the alleviation of the patient's difficulties. Usually a low point of blur and a fairly high point of diplopia means a latent hyperopia. A point of blur and point of diplopia almost simultaneous shows that there will not be found very much latent hyperopia if any at all. If the point of recovery is low it indicates a lack of control in the central nervous system and Kratometer treatments with base-in prisms are indicated. These are the cases which have puzzled some of us in the past. Often it was found that the patient was exophoric at the distance an equal amount or less at the near point, or was esophoric at distance and near and yet the Kratometer showed us an apparent convergence insufficiency at the near point. Naturally the two things are incompatible, especially the esophore whom we should consider as overconverging and yet the Kratometer shows him unable to converge at the near point. It is simply that the ability of the abduction has been worn to a frazzle and its innervations become so sadly confused that it registers an apparent paradox. The wearing of base-in prisms and the treatment with base-in prisms serves to remedy this difficulty and the pseudo convergence insufficiency disappears. This is a point where many men make a serious mistake in giving base-out treatments instead of base-in. They interpret the convergence difficulty as being due to inability of the internal recti to turn the eyes in and instead it is an inability of the external recti to let go and allow convergence to take place. These are the cases in which there is usually found a considerable latent error which has been uncorrected. Abduction is a very fascinating study and it seems that almost every time it is taken something new is learned about it.

The adduction has been a very much emphasized function and really it is less important than it seems. When it is depleted, it responds quite readily to training and isn't half the problem that abduction appears to be. Usually I take the adduction at near only as at the distance it is only a supplementary and reserve function and normally is not used. Any image upon a card such as the postage stamp or Indian card of the Kratometer serves as an object of fixation. The pupillary distance should be set at two to four mm narrower

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than the actual P. D. of the patient at near because of the fact that in adduction the eyes turn in farther than their normal during reading.

Of course the near correction is used and the prism bars are placed base out at zero. They are moved so that the prism power increases rather rapidly until diplopia occurs. The next power below this represents the amount of adduction that this pair of eyes are capable of exerting. Now take it again in exactly the same manner and if it registers more in amount than the previous trial it would indicate that innervation is good. To be sure try it again and then run the slides back again until single vision is obtained. In those cases which can increase their duction upon the second or third trial it will usually be found that their point of recovery is very close to their point of break and regardless of amount this type of patient can read with ease for long periods. However, the one whose adduction is less upon the second or third trial and whose point of recovery is low has difficulty with reading and plus lenses are not necessarily the remedy. This patient is in need of treatment with base-out prisms, if it has been found in the phoria tests which have preceded that exophoria existed at distance with at least as much or more at the near point. I never take the adduction of an esophore or myope, for as Peckham has so plainly pointed out, the esophore already converges too much and the amount is not necessary to be known. Likewise, I believe, there is danger of starting a train of innervations with the myope which will lead to an increase in the myopia.

The vertical ductions are best taken on the Kratometer in the following manner. The correction used is the one used for the distance at which the test is to be made, as well as the P. D. It may be taken in a binocular manner with the familiar card with a common X with the letter R above and the letter L below a common heavy dotted line. This calls for prism base out to fuse the two images and in cases of suspension it is an invaluable test and about the only one which will work out satisfactorily because it immediately serves as a check upon the eye that suspends. When one eye suspends in any duction one will get a false reading because the result will not be diplopia until the eye again regains its power to see. However, if this condition has been carefully investigated in the test for fusion sense and suspension is ruled out, I feel that the test with the checkerboard single card is better as no prism is needed to fuse. This leaves the eyes in a normal condition as they would be used and I feel that in anything which we do the nearer normal we make our tests the more accurate they will be.

The vertical prism slides are placed in the Kratometer base-up over the right eye and base-down over the left eye. The patient is instructed to watch the horizontal lines of the checkerboard and is asked to count them. If there are five then he is asked to inform you the moment he sees six, and the slides are slowly moved up and down respectively until this occurs. The next lowest amount is the measure of that half of the vertical duction. Then the slides are

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reversed to base-down over the right eye and base-up over the left eye and exactly the same procedure gone over again. If these amounts are equal then there is no hyperphoria present and the measure of it if there is a difference is the amount of difference between the two amounts. This is quite a simple procedure and it is not necessary to know whether it is a right or left hyperphoria as the correction is simply the building up of the weaker duction by means of Kratometer treatments with the vertical slides.

Convergence relaxation treatments should be given to esophores at all distances at which the esophoria is present. These should be given daily, if possible, and also at the same hour of the day. Those whose abduction is low but the recovery is good need only to be given base-in treatments within the limits of diplopia. That is, trying not to produce diplopia, but approaching it as nearly as possible. Then the patient is instructed to close the eyes and the slides are returned to zero and the same thing done over and over again. The time devoted to each patient should be from ten to twenty minutes interspersed with short rest periods. It is essential that no conversation should be attempted while the slides are being moved with the exception of the patient warning you if diplopia occurs. In case it has been found that recovery was poor or insufficient, then I would instruct the patient to keep his or her eyes open and as the point of diplopia is approached the slides are reversed and worked back to zero. This same thing, repeated over and over again, will build abduction both in quality and quantity but patience upon the part of the optometrist and patient is greatly needed as the recovery is usually slow.

Adduction reserve needs to be built up very rarely unless there is a convergence insufficiency present. The treatment of it is exactly the same procedure as for convergence insufficiencies.

Treatment for better motility of the eyes is accomplished by running the prism slides opposing each other rapidly up and down while the eyes are focused upon some picture or small object at the near point. This is a trouble of which the chief complainants are stenographers who are forced to look from right to left or vice versa without moving the head very much. They exhibit good ductions usually but lack in the ability to quickly change from one position to another. Sometimes it is necessary to increase the amount of their ductions by proper treatments and the basis of this is again the phoria condition. This is perhaps the reason why a certain method is so popular. Practically the same training is accomplished by instructing the patient to hold the head immobile and rotate the eyes to the right, left and up and down as far as possible. It simply brings a better blood supply to them and gives them better tone.

Vertical treatments with the Kratometer are given with the vertical prisms in the slides using an object at distance and also at near with the proper corrections refractively for the various distances. The object is to increase the weaker duction and the movement

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the slides should be rather slow. Where the ductions are equal but low all around then they should be built up, alternating first one position of slides and then the opposite. It is surprising how quickly this anomaly responds to training. There are some types of convergence insufficiencies which will not yield to treatment until the vertical ductions have been equalized.

There are pseudo and real convergence insufficiencies and the question as to which it may be is largely determined from the phoria test which has preceded. If exophoria was found at distance and near and the amount at near was as much or greater than that at distance then the convergence insufficiency is most probably a real one. There is one, however, which simulates the real thing but yet is not. This is the one produced by exhaustion and the addition of the proper amount of plus serves to cure it without treatment. It is quite easily distinguished as the patient will be found to have a considerable change in his correction and they are usually young people.

The real insufficiency is treated with the daily application of base-out. The very bad cases may be helped by the addition of base-out prism to their corrections, especially the reading one, if they are presbyopes.

As mentioned before when there is a complication of a vertical hyperphoria with a convergence insufficiency it is found almost impossible to eliminate the trouble without first correcting the vertical deficiency. Almost always it will be found that if there is a right hyperphoria and the right eye is dominant that there exists a convergence insufficiency. I think this is one of the newer things which we have learned about the dominant eye.

In the case of amblyopia it must first be determined if the eyeground is perfectly healthy and if it is not, there is no use in wasting your time trying to remedy the situation. Given a case of amblyopia ex anopsia in a healthy patient of course the first consideration is the refraction which should be carefully checked at both distance and near, regardless of age. These are cases where bifocals are almost invaluable. In attempting a phoria test it is often impossible to obtain a phoria reading and the case history must be the guide. I strive to obtain a phoria test even if I have to utilize several different appointments in order to get it for it simplifies the procedure greatly. If the phoria test has shown our patient to be esophoric, then a red or smoked glass is used over the good eye and it is dimmed to nearly the same degree of vision as its mate. Then base-in prism is run before the poor eye while it is looking at some object large enough to hold its attention. If any progress is made it will soon be evident that the details are more plainly seen than before and of course once the desire for binocular vision is aroused and encouraged it is simply a matter of time and patience upon the part of both patient and optometrist before the desired result is obtained. Naturally any supplementary work, such as reading with

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the poor eye alone, should be insisted upon. In those cases where binocular vision is lacking the use of prisms in the correction to make the patient diplopic if possible all assists toward a quicker recovery. Where the patient has a squint and vision is equal in each eye the improvement is rapid if the bases of the phoria tests are followed as a clue to the proper Kratometer work. There are a few exceptions to these cases. If an eye turns up and in, it is a case for a surgeon, likewise when it turns out and down. It is hoped that research now being conducted by some members of this Academy will result in the finding of a remedy for these conditions. There is hope, for the subject of alternating strabismus has already been conquered nonsurgically.

DISCUSSION. Dr. O. L. McCulloch opened the discussion by saying that the first essential in the use of the Kratometer is to make all measurements with the refractive correction before the patient's eyes. He also again emphasized that all phoria tests should be made with the Kratometer. He made the statement that when rotary prisms are used, there is danger of head tilting and faulty findings in phoria tests. On the fact that much emphasis is now placed on phoria test, hinges the basis of our work. He said further that the second essential in Kratometer technique is the determination of whether the patient possesses a fusion sense. He then criticized the mechanism of the Kratometer by saying that it lacked adjustment so far as pupillary distance was concerned, and that only the total pupillary adjustment could be made. Another drawback presented by him was that when trial case lenses are used, there is no provision to prevent the cylinders from turning from the desired position of their axis.

Dr. H. C. Doane inquired as to Dr. McCulloch's starting point in giving a Kratometric treatment.

Dr. O. L. McCulloch answered this by saying he always started by placing a 10 degree prism base-out over each eye, followed by this technic: To measure abduction for distance, turn slides base-in, distance correction in rear cells, P. D. set, any picture in the distance and a little below the horizon. If by use of the F-L card there is presented no suspicion of hyperphoria, we then ask the patient to look at the picture and to tell us as soon as the blur occurs, while we are moving the slides before his eyes. We make note of the blur point and then go on and note the breaking point. We then reverse the direction of our slides and note the point of recovery. When the point of blur is low and the point of break is high and recovery good, there is latent hyperopia. He repeated also that we must remember two things; first, that esophores are entitled to full correction, and second, never to take the induction at near for a myope or an esophore.

Dr. B. J. Palmer asked if you ever have the experience that patients will tell you that the lower arm of the L on the F-L chart is blurred?

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Dr. O. L. McCulloch said that this is a common statement on the part of patients if the chin rest of the instrument is too low and the card too high. Whenever such a statement is made by the patient, raise the chin rest and lower the card. If the condition persists, it is an indication of hyperphoria.

Dr. B. S. Palmer said that in the case I have in mind, I did not find a base-in or base-out prism requirement.

Dr. O. L. McCulloch replied that in such a case I would advise placing prisms so that one prism neutralized the other and run the slides up and down so as to cause the visual axis to swing in like direction.

Dr. E. E. Monroe inquired as to what method Dr. McCulloch used to determine the dominant eye.

Dr. O. L. McCulloch answered this by saying that he made a hole in a piece of paper and had the patient sight through it, thus determining which eye is seeing the target.

Dr. E. E. Monroe then asked if you exercise the non-dominant or dominant eye?

Dr. O. L. McCulloch said it makes no difference. I usually exercise the weaker eye.

The Academy then adjourned for luncheon, which was held at the Faculty Club. The afternoon session reconvened in the Physics lecture room of Columbia University, Professor F. A. Woll, occupying the chair. Professor Woll introduced Dr. R. B. Raup.

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COMPLACENCY

Dr. R. B. Raup
New York, N. Y.

Prof. Raup warned his listeners not to think of complacency in terms of smug satisfiedness, but rather in terms of its correct derivation, to be pleased with, or of a state of equilibrium such as is brought about after recovery from a mental disturbance. There are many possible disturbances lying quiet until aroused by some trivial incident. He cited the experience of the mental reaction which comes to a man who has entered a cloak room after a normal experience at lunch and finds that his hat is missing, and how this disturbance has a tendency to disrupt his complacency; that there may be a tendency on the part of some individuals to recover from this first disturbance which indicates that someone has taken the hat either in error or on purpose. The search goes on and it is found that an old dilapidated hat is left in its place. Thus another disturbance is set up before recovery could be effected from the first, and so the disturbance curve could be agitated in a series of scollop like advances upward, and it depends entirely on the attitude of the individual so disturbed as to the number of added influences to disrupt equilibrium that will occur.

Whether or not he will recover from it depends upon the dominance of the attractiveness of the act to him and his ability to analyze the nature of the cause of the disturbance. The tendency toward equilibrium, the speaker said, seems to exist everywhere and, therefore, seems to prove the existence of complacency everywhere. As a foundation for his work Dr. Raup makes the assumption that there is a continuity between physical, biological, mental and spiritual worlds, a fact must be present in all, and that everything tends to seek a balance or state of equilibrium.

Tonus of the body or any organ of the body can be said to be measured by the relationship between the disturbing and restoring influences of equilibrium. Fundamentally, the autonomus nervous system must be kept in balance in order to continue complacency. Our state of complacency is dependent upon our habit forming tendency. By law of effect, a habit becomes fixed when it satisfies.

In analyzing the process of complacency, Prof. Raup cited three stages: First, the disturbance which tended to lead away from complacency; second, the bettering of control or movement toward a reduction in the disturbance, and third, the repetition. This last

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classification, that of repetition is, said Dr. Raup, the process through which we go to establish a habit, becoming fixed only when the action is satisfying. He claimed farther that repetition is an endeavor to get the entire physical organization in accord with an act.

Dr. Raup's address was by way of explaining some of the factors that are involved in his theory of "Complacency" as it has been set forth in a book with that title. He said that complacency is the condition of dynamic equilibrium that constitutes the optimum state for the organism. "The first and chief business of living matter is to get into such relationships with other forms of matter as to maintain itself relatively constant while taking on their energy, utilizing it, and giving it off * * * * This satisfactory working relationship I have chosen to call complacency." It is the condition-from-which and the condition-to-which behavior is always in the process of moving. Annoyance is experienced when the equilibrium is disturbed by a stimulus; satisfiedness comes with the restoration of the optimum.

Evidence in support of the theory is cited from various fields. The irritability, conductivity, contractility, metabolism, and reproduction of living substance are all functions of complacency. A balance is maintained in the autonomic nervous system by the antithetical arrangement of the thoracico-lumbar and sacral divisions. Habit is the utilization of tried methods for the reduction of disturbances affecting complacency; a habit is fixed in accordance with the adequacy of its guardianship over equilibrium.

The speaker dwelt at some length upon the fact that habit is a function of this complacency condition and directed his discussion of the theory to the point where the student of vision, where he is concerned with the "habits" of the eye, could take it up and apply it to his own problems.

The meeting continued with Professor E. A. Woll occupying the chair. Professor Woll introduced Professor J. P. C. Southall.

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ANCIENT AND MODERN THEORIES OF LIGHT

J. P. C. Southall, Ph. D.
New York, N. Y.

Starting with the corpuscular theory of Newton, Prof. Southall then carried it to the undulatory theory of Huygens to establish the theory that ether had to be accepted as a fluid. He then emphasized the importance of the contribution made by Young and Fresnel when they discovered those phenomena of light known as interference and polarization to further establish the theory that ether had to be considered as a solid. Thus ended the first century in the advances made to conquer the hidden mysteries of light and its influences, and the consolidation of the studies of Optics was begun with the work of Young and Fresnel.

The speaker then referred to the contributions made by Fraunhofer in his studies of the spectrum; to Volta and his contributions to the study of electricity; to Faraday and his development of the dynamo, and then to James Clark Maxwell who, in 1873, published a book on the theory of electricity and magnetism, thus showing the relationship between light and electricity and the sequence in which the various phases were developed. The next outstanding man in the sequence of the personalities involved in the development of the facts and unravelling of the mysteries of this most wonderful natural phenomenon came Helmholtz who, from the optometrists, and ophthalmologists' point of view, has probably made the most extensive contribution to visual optics of any of the scientists working in this field, regardless of their period. The influence of Helmholtz was carried on by one of his pupils, Heinrich Hertz who demonstrated the existence of electrical waves in 1899. Then came Lorentz with his electron theory. Next Fizeau who verified the findings of Fresnel and established what is known as the ether-drift-theory, or, in other words, the assertion that when light passes through a moving medium that the ether is dragged along.

Prof. Southall then brought his talk to a close by citing the contribution made by Einstein, first with his special relativity theories and, next, with his general relativity theories which he gave to the world in 1915.

Following Prof. Southall's address, Chairman Wiseman expressed his appreciation for the contributions presented by the various speakers. He then called attention to the display of models and specimens of the eye and nervous system which had been loaned by

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the Clay-Adams Company, and invited the members to inspect them informally. This brought to a close the afternoon session.

At 6:30 P. M., the formal banquet was held at the Hotel Pennsylvania. Informal addresses were made by Mr. Roberts, Prof. Southall and Dean Pegram. All of these talks pointed toward the gratifying success Optometry is attaining by virtue of its honorable field of activity and its service-rendering scope. The speakers all agreed heartily with the principles upon which the American Academy of Optometry were founded and painted alluring pictures of the possibilities to be developed by a professional Optometry. Dean Pegram in his remarks presented an informal invitation to the American Academy of Optometry to make use of the facilities of Columbia University in carrying out research work and collaborative study.

Following the banquet, a business session was held, with Chairman, Dr. E. G. Wiseman, occupying the chair.

The following matters of interest were discussed. First, the establishment of a research fellowship in Optometry at Columbia University. Dr. E. G. Wiseman explained that Professor Pegram of that institution had invited the Academy to make use of the university's facilities, and that he believed that this was an opportunity to study some of our technical controversial problems. Second, that the American Journal of Optometry be designated as the official organ of the American Academy of Optometry. Third, that Chicago, Illinois, be selected as the meeting place for the 1928 meeting, and fourth, many of the phases entering into the matter of granting fellowship in the Academy were discussed. At the close of this discussion the Nominating Committee, headed by Dr. E. E. Hotaling, brought in the following suggestions as to the personnel of the officers to serve the Academy for the year 1928.

Dr. E. G. Wiseman, of Buffalo, N. Y., Chairman.

Dr. B. W. Hazel, of Baltimore, Md., Vice-Chairman.

Dr. J. F. Andreae, of Baltimore, Md., Secretary-Treasurer, and the following men for members of the executive council of the Academy. Dr. F. I. Tibbetts, of Little Rock, Ark.; Dr. J. H. Drakeford, New York, N. Y.; Dr. Carel C. Koch, Minneapolis, Minn., and Dr. C. E. Cox, Rochester, N. Y. These men were duly elected. This concluded the business session.

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REPORT OF THE TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY.

Tuesday, December 6th, 1927, the American Academy of Optometry reconvened at the Hotel Pennsylvania, the Chairman, Dr. E. G. Wiseman, occupying the chair. Dr. Wiseman introduced Dr. R. M. Peckham.

VISUAL NERVE TRACTS

R. M. Peckham, Opt. D., F. A. A. O.
Waterbury, Conn.

Dr. Peckham stated his regret at having been unable to prepare a written paper for the conference, and that he would be compelled to speak extemporaneously. The following notes contain some of the salient features of his address:

In commenting on Dr. Woll's lecture concerning "The Evolution of the Eye," Dr. Peckham said that his statements relative to the development of perception in the primitive invertebrate, in infra-red light, and the successive stages of color perception, recognition of red evidently being the first in this evolution, were very important points. For, said the speaker, he had discovered that the use of red lights and red objects in the development of vision in an eye amplyopic ex anopsia, with red filtered out of the images presented to the better eye, is of extremely great value.

He further agreed with Dr. Woll that nature builds to meet requirements. In the last few decades mankind has completely changed his environment and his ways of living. To meet these changes, and in adaptation of the body thereto, new functional developments are being evolved by nature. But, unfortunately, the change in our way of living has been more rapid than nature's methods of growth can keep pace with. So we find individuals striving to meet the demands of their daily work whose functional ability is inadequate. Especially is this true in the development of the function of convergence-accommodation. We meet scores of individuals lacking that full development of this, the highest form, the latest to appear, of the visual functions. Since today the larger part of our work must be done at the reading distance, it is essential that the convergence-accommodation be developed to its highest efficiency. And the innervational control of this function must be easy, unforced, well balanced.

Some accommodation is found in quite primitive animals, its

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range and efficiency increase as the species ascend. Convergence appeared on the scene among the tree-living animals. Then, in the three higher types of apes, and later in man, appears what seems to be a third function, that of convergence-accommodation. It is more than an association between those earlier functions, accommodation and convergence, seems to be an independent function, an entity, complete within itself. The brain centers and the fiber pathways of this higher function are different than those of either accommodation or convergence.

We have been prone to attribute balanced binocular functionation to perfect muscular structure. Binocular imbalances have been attributed to faulty congenital muscular structure. But perfect musculature is hard to find, in any part of the body. In our own field, if we take a hundred enucleated eyes and lay them side by side, we shall find no two eyes with exactly the same muscular structure. There will be as many variations in the position and angle of attachment of the muscles of these eyeballs as there are eyeballs under observation. We may as well take it for granted that muscular structure is invariably imperfect. It is the way in which the individual compensates for his structural imperfections that counts, far more than the imperfection itself.

One person may have a very great congenial imperfection and compensate for it readily, with ease. Another may have very slight imperfections but either suffer the extreme of distress or so completely fail in the control of ocular functions that the error seems to be very great. We must always bear in mind that an improperly innervated organ presents all the aspects of a structurally imperfect organ. Very often, especially in cases of arrested or incomplete, development of the convergence-accommodation function, it is easy, from our classical tests, to assume the cause of distress as structural, when in fact it is innervational.

There are few things more romantic, more fascinating, than the study of the development of the binocular functions. In essentials, there seems little difference between the act of a plant growing toward the light, of a flower turning to the moving sun, and the version of the eyes. And in the child, the beginning of the development of the versions is the attraction of a shining object. The neck versions of the moth are identical, in the chemistry of the afferent impulse, with the turning of the plant stem to the light. Loeb shows this beautifully in his work, *"The Comparative Anatomy of the Brain."*

The fish turns his body to bring his visual axis to bear on an object. The land animal turns his neck. The neck version preceded the eye version, but we humans retain the neck version as a subconscious reflex to widen the arc of the eye version. And some of us use the neck version more freely than we use the eye version. Such are those with low muscular mobility, as the esophore with his low ductions.

Here the speaker digressed for a moment, quoting Dr. George

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Lindsay Johnson as stating that the person who rotates his eyes freely prefers wide bifocal segments, while those who turn the head, using the neck versions rather than the eye versions get along very nicely with small segments. The question is: How are we to determine in advance which style of bifocal segment will be preferred? By experiment, Dr. Peckham said, he had found that those with poor eye versions and poor ductions would use the small segments, but those with free versions and high ductions were seldom pleased with narrow reading segments.

Another point brought out at this time was that those with poor eye versions and low ductions, who use the slow neck version instead of the swift eye version, are dangerous motor drivers. The esophore with 20/X vision, with all his energy directed to the convergence-accommodation and the maintenance of clear vision, with the ocular muscles thereby held in a state of semi-tetanus, is probably more apt to get into trouble at corners than the man of much lower vision but with free ocular motility and swift versions.

The only binocular version that is innate is the associated up and down rotation of the two eyes. In the horizontal versions, monocular excursions develop before binocular associations, and neck versions appear before binocular horizontal versions develop.

Binocular versions are the result of the semi-decussation of the optic fibers. In the fish, with his eyes at the side of his head, decussation is complete, all the optic fibers from the two retinae cross over to the opposite side of the brain. In the bird family, a few fibers remain on the same side, semi-decussation begins and the bird is the lowest animal with a neck version. As the species ascend, more and more of the retinal fibers are sent back to the brain hemisphere of the same side.

When did convergence first make its appearance? When the animals went into the trees. The earlier biologists stressed the importance, in the history of man's evolution, of the descent of the higher ape from the trees. Now, biologists sense that the ascent into the trees was of far greater import. So far as the development of binocular associations go, we have to agree with the modern thought.

The land animals had long noses, flat cheeks, eyes at the side of the head, the two visual fields either overlap very silghtly or not at all. There is no macula, though a few of the higher types of land animals do possess central retinal areas of slightly better vision than the peripheral fields.

The cat family went into the trees, began to look downward to watch enemies and get food. The eyes moved forward, the nose flattened, the cheeks developed, the smell sense commenced to dwindle and visual sense slowly superseded it. All these steps in upward progess we can study in ascending species and in the human foetus.

It seems that coincident with the development of the hand, with its reaching and grasping, is the development of binocular vision and

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its functions. Forward looking, the searching for fruit among the leaves, the replacing of a purely carnivorous diet with a partial or wholly vegetable diet, and the latter largely of fruits whose distinction among the leaves demanded the development of keener vision, this must have had its share in the development of a field of central sharp vision, in the appearance of the macula with its separate bundle of sensory fibers.

Dependence on the hand for locomotion among the tree branches, the development of the use of the hand for seizing food and conveying it to the mouth, replacing the lower animal's habit of seizing food in the mouth, of lip and tooth contact rather than paw seizure, this had its due share, no doubt, in the forward movement of the eyes, with overlapping of the two visual fields. And overlapping of visual fields demanded the development of single vision. So we find, in ascending species, more and more complexity in the criss-crossing of visual fiber pathways and of the motor pathways leading from cortical fields to ocular muscles.

Fish and bird are content with alternating monocular vision. The land animal must have simultaneous monocular vision. The rodent developed the vertical binocular association that he might look backward with both eyes at a pursuing enemy. The tree animal developed forward and down looking, a primitive form of convergence. And to this day, the vertical binocular association is innate in the human, the convergence act is an in and down rotation.

In this connection, there is an interesting observation from the study of embryology. It seems that the internal rectus and the inferior rectus are formed by the splitting of a single muscle. Whether this has any functional importance we do not yet know. We shall have to discover more about the fiber pathways over which these muscles are controlled. The details of these in the adult are unknown, much less their course and associations in embryonic forms.

When did the macula appear? Lindsay Johnson has shown that only three apes and man possess definitely developed maculae. He has also shown that only these four animals use the function of convergence, with its corollary of fusion.

Then there is the close association of the equilibrium function and the visual function, an interdependence and an intercontrol, with the equilibrium centers dominating the binocular rotations. Who shall say what influence the use of the hand in locomotion, the need for accurate placement of the image, had in the evolution of the single image of the needed binocular co-ordination?

Ocular versions are incited by the appearance of the image off the macula, by the need for clear vision, which awakens the reflex arc of ocular version to place the macula beneath the image.

Binocular versions of convergence are caused by the desire to place the two maculae beneath the two images. The result is fusion. Now there is some doubt as to whether we have not over-exaggerated

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the so-called fusional faculty, or the fusional impulse. There is very little direct evidence that the act of convergence is incited by "fusional desire." Fusion seems to be more of a result than a primary cause. The only evidence that we can at present adduce of a fusional desire is the abhorrence of diplopia, the mental distress of one who "sees double" after years of single binocular vision. And this evidence might fairly be said to point out that fusion is purely a psychic interpretation rather than mechanical act that it has been considered.

My experiments in stereoscopic vision, especially observations in stereoscopic moving pictures, give plenty of ground for the thought that possibly the fused image is in reality the swift mental imposition of alternating images. The images seem to alternate in spots, rather than as a whole. A deeper study of retinal rivalry ought to be made. It is a proper subject for very elaborate laboratory research. At any rate, I am inclined to think that our views of fusion need considerable revision and that a great deal of what has been said and written has been taken for granted rather than carefully proved.

Of fusional difficulties, or oddities, there is one most perplexing type, that I discovered in the fall of 1924. There are a great many people who fuse the peripheral images but do not fuse the foveal images. There are some who fuse the macular images but do not fuse the peripheral images at the same time. There are even some who alternate fusion of macular and peripheral images. It is a highly intriguing subject for investigation. When solved it may lead to some light on the problem of fusion itself.

Professor Ames and Dr. G. Gliddon, at Dartmouth, have likewise encountered this problem, particularly that type who fuses the peripheral images but do not fuse the foveal images. Professor Ames has denominated this peculiarity "Foveal Slip." This seems to have entirely escaped investigators in the past though the cases are very common. There is no literature on the subject.

Nearly all the binocular imbalances that we have, I think mistakenly, called "muscle troubles," seem to originate largely in the misuse by the individual, of the convergence-accommodation function. Of course, we must except from this classification those imbalances arising from toxemias. As Bing, in his Text Book of *Nervous Diseases,* so well states it, "One of the first symptoms of toxemia is the loss of associated control of muscles that are normally synergistically innervated." We find these cases in plenty. I do not wish to discuss those hyperphorias, exophorias and esophorias that arise from toxic infection, further than to call attention to the fact that many cases are diagnosed as functional imbalances that are in reality toxic imbalances. It is often hard to discriminate between the two. And sometimes both functional imbalances and toxic imbalances are present at the same time.

There are also imbalances arising from psychic, or mental disturbance. A very common type is esophoria among young women. This type is distinguished by large pupils. Accommodative esophoria,

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or esophoria caused by great exertions of the convergence-accommodation to give a clearly focussed image in compensation for considerable structural hyperopia, is characterized by rather small pupils.

For these esophoric young women with large pupils, it is a mistake to rely on plus lenses to repress the esophoria tendency. The headaches are not thereby stopped. Give plano base-in prisms for constant wear and you will find an immediate assuagement of the headache.

Here is another point on which we must revise our ideas. In our text books it is stated that pupillary contraction is an associate of accommodation. Text books on neurology contradict this. You find sentences something after this form, "It is now thought that pupillary contraction is an associate of convergence rather than of accommodation." In dissection, the pathway of the hookup of pupillary contraction with convergence was found, which caused that revision of opinion.

Now, with the recognition of convergence-accommodation as a distinct function, and with some knowledge, though it is yet but slight, we can see plainly that pupillary contraction is an associate of the convergence-accommodation function. Then, the size of the pupils becomes of as much importance to us in our diagnostic methods as it is to the neurologist in the diagnosis of psychic and visceral disturbances.

Convergence-accommodation is a highly individualistic function. It is not an innate function. It is developed by each individual, experientially. Some learn to use it well, just as they learn to do other things well. Some fail to develop the function. Others use it to excess, as the high latent hyperope with his 20/XX vision or better and the resultant semi-tetanic esophoria in his younger years and his high exophoria of exhaustion in later years.

Convergence-accommodation is an attention reflex. As a muscular act, it is incited by interest in the object whose image is refracted on the retina and relayed through the optic tracts and the external geniculate bodies to the cortical areas surrounding the calcarine fissure, in the occipital lobes. From these areas, the afferent disturbances seem to be relayed to the associative fields in the parietal lobes, whence, it is thought, spring the motor impulses that lead to the oculo-rotary nuclei. The pathway of these seems to be different from the pathways over which flow the impulses leading to versions.

Convergence alone, unassociated with accommodation must be considered as of the same type of muscular activity as the versions, direct reflex arcs incited by the sensation of the images off the foveas. But convergence-accommodation is a psychic reflex arc. That vague thing that we call "Mind," about which we know nothing, enters into the problem.

Not only are the fiber pathways over which the motor impulses to convergence-accommodation different, to considerable degree, from those over which the less complex, more physical, less psychic,

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version acts are ordered, but the muscles calling for the convergence part of the act seem to be used in a different way.

In the versions, both lateral and vertical, the commands are directed through the 6th nuclei. Each 6th controls the voluntary 3rd of the opposite side and the 4th of the same side by strands of association, or connector, fibers. The right 6th is innervated from the left cortex, the left 6th from the right cortex.

When an image appears on the left sides of the maculae, both eyes turn to the right. When the image appears on the right sides of the maculae, both eyes turn to the left.

Touch the cortex of the left occipital lobe of a monkey with an electrode and both eyes turn to the right. Touch the cortex of the right occipital lobe with an electrode, both eyes turn to the left. I have performed that experiment. The farther from the median longitudinal fissure that one places the electrodes, the farther the eyes turn. Approaching the fissure with the electrodes, the less the eyes turn. With the electrodes on the mesial walls of the longitudinal fissure, there was very slight movement. With the electrodes deep in the fissure, at the point where the macular images are thought to be discharged, there was no movement. These areas are thought to be the motor fields of unconscious versions. That is, when we turn the eyes without deliberate thought, or subconsciously, in response to images appearing on the retinae outside of the foveas.

In the posterior part of the frontal lobes, pretty well down on the outer walls, there is another area where contact with electrodes will cause ocular version. This is thought to be the area of willed version. That is, when we consciously turn the eyes in some particular direction, just because we want to, though there is no image on the retina that would cause the eyes to turn.

For a long time it was thought, and the statement is still in some anatomies, that there was no motor field in the occipital lobes. But that the motor impulses were conveyed first to the frontal lobes, thence to the oculo-rotary nuclei.

But Sherrington proved that there are motor fields in the occipital lobes, with fibers leading to the 6th nuclei. He carefully cut, in a monkey, all the association fibers leading from the occipital lobe to the frontal lobe. Then he applied his electrodes to the area in frontal lobe and the eyes turned. He then applied the electrodes to the occipital lobes and the eyes turned. That would be an interesting experiment to repeat, but it requires more exacting knowledge of the fiber tracts than many possess.

When the impulse from the left cortex reaches the right 6th nucleus it is then relayed over three pathways. One to the right external rectus, pulling the right eye to the right. One to the right 4th nucleus, which transmits the impulse over the right 4th nerve to the left superior oblique, pulling the left eye to the right. Another to the left voluntary 3rd, which transmits it over the left 3rd nerve

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to the inturning muscles of the left eye, pulling the left eye to the right. Thus, both eyes turn together to the right.

The same things happen in the left 6th nucleus when the right cortex orders a left turning. The left 6th transmits the order through the left 6th nerve and relays through the left 4th and the right voluntary 3rd, so that both eyes turn to the left.

These fiber paths resemble somewhat the way the horseman drives a team. The reins are passed, attached to the bits, so that a pull with the right turns both to the right, a pull to the left turns both to the left. The crossing over of the middle reins is much like the decussating pathways from the 6th through the 3rd and 4th.

An auxiliary pathway runs down to the 11th nuclei, through which the neck muscles are innervated in association with the eye muscles, bring head turning into co-ordination with eye turning, increasing the range of our possible fields.

Another auxiliary pathway is through the 7th nuclei, a protective pathway. Through the 7th, by connector fibers from the 7th to the 6th, eye movements, facial movements, winking, are brought into association. A similar pathway extends from the hearing nuclei of the 8th, turning the eyes in response to sound. Most complicated of all, highly essential to our physical welfare, are the pathways from the equilibration system to the oculo-rotary nuclei and the proprioceptive pathways from the ocular muscles to the equilibration areas, by which eye movements are co-ordinated with body and head movement, visual impressions with equilibration sensations. This is a most interesting study, for it involves some of the hyperphorias and cyclophorias we find. Also, a very important matter with us, lack of synchronism of visual sensation with equilibration sensation is the cause of many of the cases of dizziness and car sickness of which some of our patients complain. In these cases, we find versions slow, ductions poor, tensions of muscles, sometimes the reverse, low tonicity. All of these are matters within our realm of practice and we need to know far more concerning these fiber tracts. This phase is too large to enter into at this time, it needs and deserves, a period devoted exclusively to its study.

So much for the versions. Now, when it comes to placing and maintaining both foveas beneath both images, we need a more complicated system of pathways. Not much is known, unfortunately, about these. There have been recognized fiber paths from the right voluntary 3rd nucleus to the left 3rd nerve, fibers from the voluntary left 3rd nucleus to the right 3rd, and it is thought that through these are sent the impulses needed for this associated foveal adjustment. Imagine our horseman, who pulls both horses to the right with his right hand and both to the left with his left hand, holding an extra pair of reins in his hands by which he could pull his horses toward each other. Then perhaps you picture, in a very rough way, the use of this newly developed pathway, I say "newly developed," for it is

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only present in the higher mammals and is not well developed save in a few of the apes and in man.

Now for the accommodation pathways. They are not definitely proved. As skill in dissection advances, we have to change our ideas overnight.

From the retina, the fibers go to the optic tracts. Here they end, discharge their impulses. From here they are relayed to the external geniculate bodies. Some say there is also a relay pathway to the pulvinars of the thalami. Some deny this. There are pathways from the optic tracts to the pregemina. It was long thought that there were relay pathways from the pulvinars to the pregemina. But this is now doubted. I had fourteen dissections made by careful and competent technicians. None of the fibers said in the anatomies to pass from the pulvinar tracts to the pregemina were found.

For a long time it was thought that sensations leading to muscular actions were sent through the external geniculate bodies and that sensations of form and color were sent through the pulvinar. This is now denied. The external geniculates lie on the outer walls of the thalami. The pulvinars are the posterior portion of the thalami. It is now thought that not only the sensations causing muscular movements but also those of form and color are relayed from the optic tracts to the external geniculates. There are fibers connecting the external geniculates with the pulvinars. There are also fibers connecting the two external geniculates. There are fibers connecting the two pulvinars.

The fibers from the retinae end in the optic tracts in the same relative position as their outer terminals in the retinae occupy. The same relative position is carried into the external geniculate bodies. In reality, the external geniculate bodies are continuations of the optic tracts.

Histologically, the optic tracts and optic nerves resemble the gray matter of the brain. They do not appear, under the microscope, like the gray matter of true nerves.

From the external geniculate bodies and from the pulvinars are heavy masses of fibers leading to the occipital lobes of the cortex and to the frontal lobes.

The occipital lobes have always been considered as the seat of visual impressions. Lately some physiologists have advanced the theory that some visual impressions are conveyed to the frontal lobes, but nothing tangible has been brought forward in proof. We shall have to continue with our thought that the visual centers lie entirely in the occipital lobes.

Accommodation impulses pass through the pregemina. (The word pregemina is a recent abbreviation for the long term "Superior Colliculi of the Corpora Quadragemina.) The question is: Is accommodation incited over the pathway from the External Geniculates or must the sensory impulse first pass to the cortex of the brain

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there to be transformed into a motor impulse, sent to the pregemina to be relayed on through various nuclei to the ciliary muscles? There are very conflicting opinions as to this.

Primitive impulses are completed through the bodies of the brain stem and spinal cord without reference to the cortex. Only impulses requiring mental attention go through the cortex. Is accommodation that type of primitive impulse that can be completed, in response to retinal blur, without direct mental attention?

The muscles of accommodation in the bird are voluntary muscles. In mammals, the muscles of accommodation are involuntary muscles, that is, like the muscles of heart, stomach, intestines, glands, etc., they are operated without mental attention. They are autonomous.

Is accommodation an innate function? There is dispute as to this. Some say yes, others say no. Do we accommodate, can we accommodate, when we are born or must we wait until the nerve pathways are developed, a few weeks after birth. No one knows.

Sensory nerves are gray matter covered with a white sheath. The connector nerves of the brain are not covered with this white sheath or myelination, until the individual is ready to use them. The nerves from the external geniculates to the occipital lobes do not take on their white sheaths until the baby is three weeks old. That is when "He begins to see." That means, his consciousness has so evolved that he is ready to use his eyesight. Now if accommodation is not an innate function, and if accommodation requires cortical attention, then the pathway from the external geniculates to the cortex are essential to accommodation. If these pathways are not essential, if accommodation is a primitive function, if its reflex arc is completed through the pathway from external geniculates to pregemina, then the cortical pathway is not necessary. I proposed to prove this one way or the other by cutting the fibers from external geniculate to cortex, in a monkey, permitting him to recover, and then test his accommodation. The first attempt with the experiment was a failure and I have not had opportunity for another trial.

At any rate, we do know that the impulse passes through the pregemina. From here there is another question, not satisfactorily proved, to which I will return in a moment.

The next relay is the involuntary part of the 3rd nucleus. It seems very odd that the students in all but one of our schools have never been taught that the 3rd nucleus and the 3rd nerve are in fact three distinct nuclei and three distinct nerves, not at all associated, and having no influence one upon the other. Had this been given the attention it should have received, most of the things that have been written about associations between convergence and accommodation would never have been uttered.

The involuntary 3rd consists of two parts, the nuclei of Edinger Westphal and the mesial nucleus. From the pregemina, fibers go to the nuclei of Edinger-Westphal, thence to the mesial nucleus, then to the ciliary ganglia, then into the fibers of the ciliary muscle.

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Now here is another question awaiting solution. The ciliary muscle is in fact three distinct muscles. There is a bundle of circular fibers, surrounding the lens, imbedded in the ciliary processes. When they contract, the ciliary body is pulled forward, toward the lens, the suspensory ligaments are relaxed, the lens becomes more convex. That these receive their innervation through the involuntary 3rd is well enough established.

Antagonizing these are the radial fibers, which in contracting pull back the edges of the ciliary body, tighten the suspensory ligaments, flatten the lens. Whence do they receive their innervation. No one knows.

Then there are the meridional fibers, attached at one end to the sclera at the base of the iris, inserted at the other end into the choroid. When they contract, they pull the choroid forward, the ciliary body moves forward, the lens becomes convex. Whence comes their innervation. Clinical evidence indicates that it comes through the spinal sympathetic system. Anatomical evidence supports, to some extent, this view, though the full path of the fibers has not been definitely mapped out. Physiological evidence is lacking.

From the pregemina, besides the fiber tracts to the involuntary 3rd, there are other bundles that pass down the brain stem to the cervical segments of the spinal cord, where they discharge in an area known as the cilio-spinal center of Buge. Here the impulses are picked up by another relay of fibers and carried into the superior cervical ganglia. Thence emerge fibers to the intrinsic muscles of the eye.

It is known that this pathway just described carries the impulses that dilate the pupils. It is thought that they carry impulses to the meridional fibers and the radial fibers of the ciliary.

The superior cervical ganglia are at the head of two long chains of sympathetic system ganglia, connected with and innervating the involuntary muscles of the skin and internal organs of the body. This is known as the spinal sympathetic system.

All muscles have antagonists, either other muscles or elastic tissue. In the involuntary system one set of muscles is innervated by the spinal sympathetic system, the opponents by the para-sympathetic system.

The sphincters of the iris are innervated by the para-sympathetic system, the dilators, by the spinal sympathetic system. The involuntary 3rd is a part of the para-sympathetic system.

When any of the vital organs is so affected that extra effort is demanded from either para-sympathetic or spinal sympathetic centers, the influence spreads throughout the entire system, all organs are more or less affected. When one system is over active, the opponent is proportionately inhibited. Tonicity of the muscle that is put to extra work is increased, a corresponding amount of tonicity is withdrawn from the antagonist.

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When there is a disturbance of the digestive organs or of the sexual organs, such that the spinal sympathetic system is called on for extra duty, we get a reflex in the eyes by a dilatation of the pupils. Or if the para-sympathetic system is overworked, we have contracted pupils.

In the myopic eye, on dissection, we find the meridional fibers very heavily developed, the circular fibers are few and small. When a muscle is used it develops in size and in tonicity. When it is unused, it grows smaller, its fibers waste away from lack of tonicity, lack of use. The nerve fibers to it degenerate.

I have several slides made from known myopic eyes. In all of them, the meridional fibers are heavy; under the microscope they look like great cables. In one of them, there are no circular fibers to be found, and but slight traces of radial fibers. In the others there are a few tiny circular fibers, a few weakly developed radial fibers.

The most advanced thought is that myopia is a symptom of visceral imbalance, that the reflexes have spread throughout the spinal sympathetic system, contracting the meridional fibers of the ciliary, putting them into a state of tetanus, what has been falsely called "Spasm of the Accommodation." Likewise, the pupils are highly dilated, as we can see without a microscope. On dissection, the dilatators of the iris are seen to be heavily developed, the sphincters very slight, evidently weakened, since all tonic and trophic innervations have been withheld.

On the other hand, we find the circular fibers of the known hyperopic eye to be heavily developed and the radial fibers, their antagonists, are very few in number. The meridional fibers are also underdeveloped.

Several physiologists have experimented with spinal sympathetic innervation of the ciliary, with negative results. They have learned nothing. But they are decidedly wrong in therefore assuming that there is no such innervation. Their experiments were not sufficiently thorough, probably they lacked equipment, doubtless they needed more knowledge. We are not to consider the problem as settled. No better undertaking could be assumed by optometrists than the attempt to solve this question. It would mean years of work by skilled laboratory workers, the expenditure of thousands of dollars. But it is a question that must be answered, and to the optometrist it is of particular importance. For therein lies the answer to the vexatious contention that atropine is the only way of determining the amount of latent hyperopia.

Atropine only paralyzes the para-sympathetic nerves. Only the action of the circular fibers of the ciliary is abrogated. Further, when the para-sympathetics are rendered non-conductive by atropine, their normal tonicity is discharged into the spinal sympathetics. That is why the pupils dilate so rapidly, why the heart beats faster and irregularly, why the face flushes.

Now we can conceive of two reasons why we can often find more

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latent hyperopia after three or four days' use of atropine. One is that the radial fibers, in a highly hyperopic eye, may be slight and weak. Possibly, if it is true that they are innervated by the spinal sympathetics, they cannot receive the full tonic discharge that is switched from the para-sympathetic system under inhibition. If that could be possible, then we could see that the para-sympathetic would not be fully inhibited. That is an experiment I hope to make some day. Another conceivable supposition is that the excess tonicity is sent into the meridional fibers, causing them to contract in the same manner that the dilatators of the eye are forced into excessive flexion. Neither of these suppositions, and that is all they are, can be denied or affirmed, until the question of spinal sympathetic innervation to the ciliary is proved or disproved, finally and without doubt.

Dr. Savage made a noteworthy statement at the 1927 Ophthalmological Congress. He said that no known drug would paralyze Bowman's muscle. Bowman's muscle is the old name for the meridional and radial bundles of ciliary muscle fibers. Such a statement from such an active protagonist of the use of atropine as Dr. Savage has always been is worth attention.

We even have records on file of myopic children being carefully measured as to the amount of myopia, then put under the influence of atropine for three days and becoming more myopic. Surely, all these things mean something. Let us find out the truth, if it be possible.

Nicotine is the only known drug that will render a spinal sympathetic nerve non-conductive. And it has to be applied to the naked axis of the nerve as it emerges from the spinal cord. Not a usable method in routine refraction work.

A word as to the pathway of pupillary contraction. Fibers are found paralleling the accommodative route fibers from the third nucleus to the eyeball. These are known to carry both light reflexes and the associated contraction that accompanies convergence-accommodation impulses. Possibly there are two sets of fibers for these two different tasks. And the associated convergence-accommodation pupillary contraction has been satisfactorily traced from pregemina to third nucleus. But the light reflex pathway is still open to investigation. How it gets from the optic tracts to the third nucleus has not been assuredly determined. It has always been stated that the pathway is through the external geniculates and pregemina. But now that whole theory has been shown to be entirely speculative by some German physiologists. Several researchers have shown that the sphincters of the iris retain the qualities of primitive muscle, which reacts from contact without the interposition of a nervous system. After cutting both the sensory nerves from the sphincters to the central system and the sensory nerves from the retina to the optic tracts, also severing the motor nerves to the sphincters from the central system, they found that the iris would contract to bright light. So far as is known, this is the only muscle in the human body that still possesses

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the autonomous contractility of the muscles of primitive invertebrates.

Having covered, somewhat sketchily, but as well as time will permit, the pathways of the versions, of independent convergence, of accommodation, of pupillary control, we can revert to the convergence-accommodation pathway. It is thought that the sensations discharged in the occipital lobes are transmitted over association pathways, to the parietal lobes. Here associative memory plays its parts. Old impressions are reawakened, the picture is compared with sensations received in the past by way of touch and pressure sensations, heat sensations, auditory impressions, word pictures, etc. The whole is fused into a new picture, recognized for what it is. The upper part of the parietal lobe has been shown to be an associative field for the information we gain from the various sensations.

Further down is the field of word forming. Near this is the motor field that arouses the convergence-accommodation function into activity when the image received in the retina is out of focus, when the "picture," for we have no better word, is not clearly delineated to this unknown observing function that we call Mind.

From here the fiber pathways seem to pass forward to the pregemina. And here they terminate, form new bundles and pass to the oculo-rotary nuclei. Now enters the most astonishing thing of all, when we consider what we have been taught in the past. If this be finally proved true, then optometric procedure is subject to considerable modification, on its theoretical basis, at least, if not so much in its practical application.

The evidence, at present, points to a simultaneous innervation of the 4th nuclei, which supply the superior obliques, and the involuntary division of the 3rd, which supplies the circular fibers of the ciliary and the sphincters of the iris. And the voluntary section of the 3rd, controlling the internal recti seem to be left out.

However, we must not go too fast nor jump to conclusions too readily. Without doubt, there are other associative pathways, not yet discovered, that bring the internal recti and inferior recti into the association. But this much we may be fairly safe in accepting, that there is no known pathway by which the internal recti are brought into associated activity with the function of accommodation.

There is another point to be remembered. Cortical innervations, that is, motor impulses from the cortex, are never, in any part of the body, sent to the muscles that are to be used in the willed act. The cortical impulses are sent into nuclear areas, where they are sorted and arranged, directed to the specific muscle or muscles that are to be used. The action of the muscle and its association with other muscles is arranged by reciprocal innervational pathways interconnecting the nuclei of the nerves that supply the muscles.

We have just enough information now about these associations of extrinsic and intrinsic muscles to make us seriously question our classics, enough to show that our writers have been speculative in the

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extremist of extremes, enough to awaken our curiosity and start us out into real investigative work, determined to discard the speculative, to seek for facts.

The 6th nuclei and the voluntary divisions of the 3rd when innervated in the willed acts of version and convergence receive the impulses through the medial longitudinal fasciculus, which arises from two pairs of nuclei in the roof of the midbrain. These are the interstitial nuclei of Cajal, which lies in floor of the third ventricle, and the nuclei of Drakschewitsch which lie in the upper and forward sides of the pregemina. It is thought that the impulses leading to eye rotations are sent from the oculo-motor fields of the frontal lobes through the nuclei of Drakschewitsch. The right 6th receives fibers from the left bundle of the medial longitudinal fasciculus, the left 6th receives from the right bundle.

Both right and 3rd nuclei receive fibers from both right and left bundles of the medial longitudinal fasciculus. The right and left nuclei of Drakschewitsch are connected by a commissural bundle of association fibers, running through the posterior commissure of the brain stem. Thus, by this commissural bundle and the semi-decussation of the fibers from the medial longitudinal fasciculus, the 3rd nuclei are brought into that integrated association demanded in the complex movements of lateral, vertical or oblique rotations with maintenance of convergence of the visual axes, so that the foveas will remain beneath the two images throughout these ocular excursions, constant single vision will obtain.

By the pathways of control from each 6th to the opposite 3rd, reciprocal innervations and inhibitions, essential to balanced binocular movements, are enforced. The control of the 4th nuclei from the 6th is a part of this system. The whole presents one of the most beautiful pictures of co-ordinative pathways to be found in the body.

The 4th is innervated from the visual motor nuclei in the pregemina. These fibers pass downward from the pregemina through the medial longitudinal fasciculus to the 4th nuclei. For a long time it was thought that these fibers were functioned within the medial longitudinal fasciculus and they are so given in many anatomies. Recent tracings show these fibers to the 4th are not a part of the system just described as feeding the 3rd and 6th. The 4th seem to be excluded from direct control through the medial longitudinal fasciculus while the 6th and voluntary divisions of the 3rd do not appear to be controlled from the pregemina. The fibers from the pregemina to the 3rd are evidently all involuntary fibers to the involuntary nuclei of Edinger-Westphal.

This is an important point. For here is a part of the evidence of the associated innervation of the superior obliques with the circular fibers of the ciliary and the sphincters of the iris in the functionation of convergence-accommodation. It is also part of the evidence that makes us doubt the direct association of the internal recti in the act of convergence-accommodation.

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Then we run into another block that gives us pause. For there is no agreement as to the rotation of the eyeball that is caused by the flexion of the superior oblique. The old anatomies give this as an out and down rotation, an error still persisting in some of the anatomies and in most of text books. A later idea has been promulgated by some ophthalmologists that the rotations produced the superior obliques are in and down. Now a third theory is presented by the neurologists, who say that the rotations are in and up.

Touch the right pregeminum of the monkey with an electrode and the left eye rolls in and up. Touch the left pregeminum and the right eye turns in and up. Touch both pregemina and both eyes turn in and up and the entire body begins to jerk and quiver. I have performed this experiment, which is described in several books on nervous diseases, and the results are as stated.

But the act of convergence-accommodation carries with it an in and down rotation of the eyeballs. So there is still something to be learned about these innervational pathways. Either the neurologists are wrong and the ophthalmologists are right about the action of the superior obliques in the human, or there is an undiscovered pathway bringing the inferior recti into association. This is another problem that might be undertaken by a research organization of optometrists.

The neurologists assert that an in and up squint is a symptom of disturbance in the pregeminal pathways. That the superior oblique is in a state of tetanus as the result of a spasm, or convulsion. When the pregemina are affected, or when one of them is affected, by diseased conditions, there is a noticeable interference with ocular rotations. Accommodation and pupillary contraction are nearly, sometimes totally, suspended.

In squint of the in and up type we will note that invariably the pupils are dilated. With skiascopy we find an abnormally high lag of accommodation. This has been considered as an evidence of latent hyperopia. But this, I think, is a wrong conclusion. It is more probably an evidence of the partial suspension of the convergence-accommodation function. Plus lenses will not assist in the straightening of the deviating eye. In fact, the patient usually grows more cross-eyed when wearing the heavy plus found by dynamic skiascopy.

Until a very short time ago, in and up squint was considered incurable save by operation. But in the last year, two Academy members, considering the above data, have succeeded in straightening cross eyes of this type. Dr. G. M. Martin, of Utica, N. Y., and Dr. Frank H. Roberston, of Blackwell, Oklahoma, working independently, neither knowing what the other was doing, have evolved a technique, identical with both, of straightening these eyes. The strong plus lenses are omitted, base-up prism over the squinting eye is given for constant wear, and by Kratometer treatments, bases-up over the squinting eye, the tetanus of the superior oblique is broken, the eye

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is brought to straight position. Convergence-accommodation begins to function and there is reduction of the plus seen in skiascopy.

The gratitude of the Academy, of all Optometry, is due to these two members.

And out and down squint, conversely, would indicate a paralysis of the pathway supplying the superior oblique. One would say, off hand, that such a squint would be incurable by prismatic treatment. However, an optometrist in Kansas, whose name at the moment I forget, showed me photographs of a case of out and down squint that he had corrected by Kratometer exercises. In this case, either there was not a total paralysis, some of the fibers in the pathway still retained conductivity, or the exercises had awakened such interest in the central system that another pathway was built.

We must remember two things. That nerves can be regenerated, do regenerate, not only after operations in which they have been cut if the operator carefully brings the cut ends together, but also following a diseased condition during which they become non-conductive or their nuclei become non-irritable. Or, failing this, the central system will often build another pathway, over some round-about route, to the muscle. The essential feature is that the central system shall be awakened to the necessity of such building. It seems fair to believe, with the evidence before us, that exercises may sometimes awaken such an interest.

All muscular activity, of whatever sort, is the result of disturbances in the central nervous system. We are thrown out of balance with environment by sensory messages to the central system. Our immediate act is the innervation of muscles so that we may be brought back to a state of content with our environment. Doubtless Professor Raup brought this out very clearly in his lecture on "Complacency." Personally, I consider his book on *"Complacency"* one of the most important contributions to optometry that has ever been made, though it was written with no thought or knowledge of optometry's peculiar problems. But in it are set forth fundamental conceptions of the physiological and psychological reflexes from which all human activity results. It is a book well worth careful perusal by our Academy members. Such study will show the errors into which many of theorists have been led.

Muscular activity is induced by dissatisfaction. The force of the muscular action, its quickness, energy, efficiency, is determined by the extent of the dissatisfaction, is proportioned by the interest excited. That must be the foundation on which we shall build our technique of innervational treatments.

Convergence-accommodation is an attention reflex. That statement cannot be reiterated too often. Its efficiency is based wholly on the interest awakened in the cortical centers, by the extent to which the blurred images create dissatisfaction. Given interest in the object, convergence-accommodation is enforced. When interest is lacking,

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when curiosity is not awakened, the function is not used to its fullest possibility.

In testing vision, I have been greatly surprised to learn that in many adults letter vision is poor, but given some other test object, something that awakens the curiosity of the subject, vision will sharpen up considerably. In testing the vision of small children, I have found that colored pictures awaken more interest, with consequent better visual records, than do the ordinary black drawings that we use on our test charts. I have also found that sometimes if the mother sits across the room and holds the test target that the child will give better answers than when the same target is shown in the test cabinet.

These are illustrations showing what I have attempted to bring out, that sharpness of vision depends much on the interest awakened. Attention must be incited, curiosity awakened, dissatisfaction with the blurred image must be present. Convergence-accommodation only results when there is discontent, "complacency" must be disturbed.

Here, I think, is the basic answer to the question as to why some persons are latent hyperopes while others do not make the effort to compensate for their structural hyperopia. These latter are not greatly disturbed by the blurred images, they are not sufficiently interested in the objects at which they are looking. The former are of a curious, investigative type of mind. They want to see. Therefore, they make the effort, they do see clearly, in spite of the possible strain involved.

Consider the non-presbyopic adult with 20/XXX or 20/XL, or possibly with worse, vision. He shows a manifest hyperopia, needs plus lenses, perhaps needs cylinders, to clearly see the distance test chart. But hand him fine print, a photograph or print, a piece of engraving with fine lines, anything to hold in his hand and look at closely, he will see the finest details. He will compensate his structural error and get clear vision. Why? Because his interest is awakened.

We do not measure "visual acuity" with our tests. It is wrong to use that term. What we measure is letter vision, and the determination of that measurement depends solely on the interest the subject has in those letters. His acuity may be good, it is, for he sees what he wants to see. We have as yet developed no technique for measuring "visual acuity," for we cannot separate the interest factor from the resolving power of the eye.

A few years ago I was making an optometric survey of the employees of a brass factory. One of the young women had 4.50 D. of astigmatism in the right eye, 4.00 D. of astigmatism in the left eye. The axes were oblique. Vision at distance was about 10/CC by the letter charts. In the near tests with printed matter, she made horrible work of even large print. I inquired as to the work she was doing. Was amazed to find she was inspecting the brass ferrules of pencils.

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Of course, I went to the factory superintendent with the records, inquiring why a girl with such poor vision was doing such work as inspecting, which required the finest visual discrimination. Looking up the girl's records, we found that she had been an inspector for twelve years, was one of the fastest and most accurate of the inspectors. She compensated her structural error because she wanted to see her work. With printed matter, she did not compensate because she was not interested. With pictures I found her near vision was most excellent. With distant colored test objects, pictures that would awaken her interest, her vision was better than 20/LX, as nearly as I could estimate it. Compare that with the letter vision of 10/CC. Again, I repeat, convergence-accommodation is an attention reflex, a psychic matter, based on the interest awakened, proportioned to the dissatisfaction with the blurred image.

Take the child of eight or nine with 20/XX or better vision. Somewhat better than we normally expect at his age. You will find him a curious, interested, alert boy. If you make a thorough examination, you will probably find considerable latent hyperopia. You are apt to find a little esophoria at distance.

What is accommodative esophoria? Whence its origin? On dissection, we find that the convergence muscles are actually hypertrophied, are heavy, strong bundles of fibers. The anatomists of the last century, finding this, concluded that this was a congenital structure. Hence, the recommendation of operative measures.

Today, we doubt that this is a congenital malstructure. For muscles develop with use. They are kept constantly in a state of tonicity, so long as an exhaustion period is not set up. While in this state of high tonicity, their cells are rounded, the muscle is in consequence short and thick. When the exhaustion stage appears, the cells lose their roundness, tonicity is low, the muscle lengthens, is thinner. That is why we often find middle-aged men esophoric in the morning, exophoric in the evening. In the morning fresh, tonicity high. In the evening tired, tonicity low.

At the same time that we find the convergence muscles thus highly developed, in the known esophore, we also find the circular muscles of the ciliary equally overdeveloped. Why this development? Evidently because at an early age the individual learned to use his convergence-accommodation. The muscles are in consequence very highly developed. Their antagonists are correspondingly underdeveloped, sometimes partially atrophied.

Accommodative esophoria, therefore, is to be looked upon as a sign of the excessive use of the convergence-accommodation function. We know, from experience, that if we can correct the larger part of the latent hyperopia, if we can persuade the patient to wear his full correction, that he will be fairly comfortable. That is, if he can tolerate blurred distance vision. After a time, some of these patients will learn that by not using their convergence-accommodation, they

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can have clear distant vision with the strong plus lenses. But such are few. The majority cannot adapt themselves.

The esophore's natural reaction to a blurred image is the use of convergence-accommodation. That trick was learned in early youth, has become a fixed habit. So we frequently find an esophoria increased by strong plus lenses, when those lenses blur the distance vision. Relaxation of the convergence-accommodation is unknown to the patient. His "set" is toward the positive act, the negation is impossible.

With base-in prisms we can enforce this relaxation. For such prisms deflect the images to the nasal sides of the foveas. The reflex act is the innervation of the 6th nuclei, to turn the visual axes outward. Innervation of the 6th means inhibition of the 4th and 3rd, through the associative pathways connecting these nuclei.

One point in connection with inhibition. Inhibition is only accomplished by innervation of the nuclei antagonistic to the nuclei we wish to inhibit. We do not inhibit a muscle. We inhibit the innervation of the nucleus of the nerve supplying the muscle. The only way to accomplish this inhibition is by innervation of the antagonistic nuclei.

So we inhibit convergence by innervating the 6th nuclei by base-in prisms that place the images on the nasal sides of the foveas. The reflex arc of an image on the nasal side of the fovea is the innervation of the 6th nuclei with reciprocal inhibition of the 4th and 3rd. Such prisms must be of equal power over both eyes. Prism over one eye only innervates one of the 6th pair, only inhibits one of the 3rd pair and one of the 4th pair.

The reciprocal inhibition that follows the innervation of a nucleus, has been found to extend far back into the pathway leading to the inhibited nucleus. That is, not only is the nucleus itself inhibited, but there is inhibition along the entire pathway back to the original source of the innervation. Sherrington thought that the property of reciprocal innervations lay entirely in the nucleus. Later physiologists have found that reciprocal innervations are developed farther back in the pathway.

So with base-in prisms, with their innervation of the 6th, the antagonistic inhibition extends not only to the 4th and 3rd nuclei, but beyond them, with inhibition of the pregemina and convergence-accommodation, with inhibition even behind these to the cortical fields themselves.

Thus is it possible the complete abrogation of convergence-accommodation that we find when we use strong base-in prisms. For there is a point where, when we suspend convergence we also suspend accommodation. Thus we can determine very closely the amount of latent hyperopia with base-in prisms, and we find, by comparative tests on the same people, that we can determine the latent hyperopia more accurately with base-in prisms than with atropine.

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There are some theorists who have denied that this is possible. We can dismiss them with this, that in their writings they show very little acquaintance with the visual fiber tracts, very little acquaintance with physiological functions. Their denial is also based on speculative theory, for they admit that they have not given the method full experimental trial. And no one is in position to affirm or deny the value of any method or proposition until he has given it full and exhaustive trial.

The Maddox theory of over convergence by the esophore with following adjustment by the "faculty of supplemental divergence," is not found to be true. By laboratory methods, I have seen that the esophore does not over-converge and then come back to the point of fusion. He converges to the point of the single image, the visual axes do not pass their appointed intersection in the object of regard. The foveas rotate to the point of placement beneath the image and there halt.

It is only when we so displace the two images that only one fovea can be placed beneath its image at a time, as in the Landolt method of finding the horizontal phorias with base-down prism over one eye, or when we give to each hemisphere of the brain a different object to think about, as in the Maddox Rod test, that the visual axes converge too far. They do not over-converge during the act of binocular fixation.

Base-out prisms should never be given the esophore in so-called "position of correction," for such prisms actually force the over-convergence. They develop still more tonicity of the convergence muscles, the esophoria is increased.

Base-in prisms may well be given to all esophores. For such prisms inhibit the activity of the convergence muscles, withdraw tonicity impulses from them, divert that tonicity to the abducting muscles which have been in a state of lowered tonicity. We must always bear in mind, that when a muscle is made to contract, tonic impulses are sent into it and an equal amount of tonicity is withdrawn from the antagonist. If we can but remember that at every step, we shall not fall into erroneous prism prescription.

There is no such thing as "prism in position of rest." A prism always innervates the muscle beneath its apex, adds to its tonicity. The muscle beneath the prism base is always inhibited, tonicity withdrawn from it.

The use of the superior obliques in the convergence-accommodation and the control of the 6th nuclei over the 4th, gives us an understanding of the spurious hyperphoria so often found in cases of esophoria with latent hyperphoria. When we use our base-in inhibitory prisms and supply the needed plus correction, this hyperphoria disappears. We find that this spurious hyperphoria is invariably a left hyperphoria in right-handed persons, a right hyperphoria in left-handed persons.

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Myopia can be reduced, many times, by the use of base-in prisms. Or, if it cannot be reduced appreciably, vision can be greatly improved. Just why this improvement in vision occurs, I do not know. An ophthalmologist friend who has noted this suggests that it is because the withdrawal of tensions increases the blood circulation in the retina. That is a very plausible explanation, but even if it is true, we shall have to work farther back and find why the circulation is bettered.

Just as esophoria is to be regarded as a symptom of hypertonicity of the convergence muscles, so is exophoria to be looked upon as indicative of their lowered tonicity. Orthophoria is not to be considered as an indication of perfect muscular structure as the anatomists of the 19th century thought, for the normal muscular structure is such that the visual axes diverge widely. Orthophoria is an indication of tonic balance of the extrinsic muscles.

Emmetropia is hardly a condition of structural perfection for we find all emmetropes are structurally somewhat hyperopic. When we find emmetropia with orthophoria, there is always quite a degree of latent hyperopia.

The causes of exophoria are many and varied. Very few exophorias originate in the troubles of binocular functions. Most of them are symtoms of physiological, sometimes pathological, disturbances in other organs.

Comparison of distant and near phorias is of great value in diagnosis, especially if made before refractive errors are corrected. The phoria test made after correcting lenses have been supplied is of very little value unless compared with the phorias made at the beginning of the examination. Phoria tests are not "muscle" tests, they tell little about "strong" muscles and "weak" muscles. But they do tell us much concerning the habitual convergence-accommodation habit of the individual.

Duction tests do not measure "convergence reserves" or "fusional reserves." In fact, we gravely doubt if there is any such faculty as is indicated by those terms. They seem to have been coined in the need for representing such theoretical proposals based entirely on speculative thought, not on actual research, as we of today consider research.

Probably induction is poor in esophoria because the muscle is already in a state of hyper-tonicity, unable to accept an added load. Ductions may be low because of hyper-tensions, because of impaired nerve conductivity, because of a non-irritable condition of the muscle. The whole is a physiological problem and needs laboratory research to do away with the guessing of the past.

Negative relative convergence at the near point is a valuable aid in diagnosis, a feature that has not been given the consideration it deserves.

When the negative relative convergence is low, we have a sure

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sign that the patient's complaint arises from an uncorrected latent hyperopia. With comfortable near vision, the negative relative convergence runs around 15Δ to 18Δ, depending somewhat on the interpupillary distance. It should equal, we find, the meter angle of convergence at the distance at which the test is made. When less than this, latent hyperopia is surely making trouble, must be determined and corrected.

Latent hyperopia lies at the root of many of the esophorias, exophorias, hyperphorias and cylcophorias that we find. The latent hyperopia must be determined in every case before we can safely proceed with our corrective methods. No examination is thorough, none is worthy the name "examination," that does not include a determination of the latent hyperopia and the negative relative convergence.

We should be very cautious about base-out prism treatments. They must not be given when the cause of the low induction is associated with latent hyperopia or with esophoria of any type. In those cases, base-in treatments are called for. We find that treatments with base-in prisms are the quickest and surest way of raising the induction in cases of hypertensions.

Base-out treatments may only be given when an exophoria arises from low body tonicity or when the low induction can surely be ascribed to low nerve conductivity or to non-irritability of the muscle. And then general bodily exercise should regularly accompany the prism treatments.

Another problem that confronts us is presented by the many cases of under developed functionation of the convergence-accommodation. These cases have been miscalled "premature presbyopes." The high plus movement found in skiascopy has been falsely labeled "latent hyperopia." This is in reality, I believe, a lag of the convergence-accommodation. Plus lenses are not needed, are wrongly prescribed. Base-out prisms will enforce some attention, awaken cortical innervation. Base-out treatments, using brightly colored pictures for targets, in particular red pictures, will incite the attention reflex needed.

The speaker went on to detail methods of examination procedure and suggestions for the treatment of various imbalances.

In conclusion he called attention to the need of a better understanding among all refractionists, both the optometrists and the ophthalmologists, of physiological principles. The problem of the refractionist has been considered as largely an optical problem; he has concerned himself with correction of manifest errors. But the manifest error is but a symptom. It is not the cause of the distress but a sign of the cause. We must learn to look for causes, remove causes, cease the treatment of symptoms.

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REPORT OF THE TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY.

The meeting continued with Chairman Dr. E. G. Wiseman occupying the chair. Dr. Wiseman introduced Dr. E. LeRoy Ryer.

CONTROL OF MYOPIA BY REVERSE STEREOSCOPE

E. LeRoy Ryer, Opt. D., F. A. A. O.
New York, N. Y.

For the moment or until we can advance a better one, let us not quibble over the term "Reverse Stereoscope." We call it that because it contains base-in prisms and minus lenses in place of the base-out prisms and plus lenses of the true stereoscope. It serves to convey the idea in a simple way and to that degree at least is justified. It may be built in the form of a stereoscope, with head piece and rack to hold the object viewed or, better, as a head loupe with fiber or tape band. Its object may be obtained by using loose prisms and lenses in an ordinary trial frame, or, in direct practical application, by grinding the sphero-prism combination and setting it in an ordinary spectacle frame after a few trials with one of the above to point the way to a reasonably permanent combination.

Most of our investigations were carried on with the Refractor or the Kratometer but, of course, one of the above forms must be used when the principle is to be applied for home use outside of the refracting room. Any phoro-optometer or phorometer will permit investigation of the principles here set forth, we believe for the first time. If sufficient care be exercised in setting the base-apex line of the prisms correctly, a trial frame and loose prisms and lenses may even be used, but we must urge great caution in using loose prisms in this technic, as well as in all muscle work.

Such claims as we may make for this improved technic in the handling of progressive myopia are based upon a very simple premise, namely, that in any case of myopia showing a tendency to increase, the use of the eyes at long range is to be preferred to the use of the eyes at close range. Starting from such a premise we arrived at our conclusions along the following lines:

Mindful of the work done by some master minds of the past we cannot blame you if you consider audacious any attempt to carry the conquest of this dreaded condition of progressive myopia a step further but we trust you will not consider this attempt presumptu-

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ous. Our present methods are certainly not all we would wish them, hence we must be hopeful or hopeless, optimistic or pessimistic, and we prefer to believe that there is a better way somewhere and that perhaps that which we are about to suggest may carry us a little further along that better way.

Donders, after his usual keen, penetrating investigation, concluded that myopia should be given its full correction, as early as possible, to be worn constantly for both distance and near. In extreme cases he admitted reluctantly the possibility of helping by removing the crystalline lens.

Landolt felt forced to modify this treatment somewhat and advocated full correction, as early as possible, for distance, but for near a reduced correction. In extreme cases he advised a tenotomy of the external recti.

While others hinted at the use of base-in prisms it remained for our own Peckham, whose name some day will be enshrined with those of Donders and Landolt, to show most clearly their paramount importance in all cases of myopia. He advocates a distance correction composed of a base-in prism and the weakest minus spherical compatible with binocular balance and always a stronger base-in prism and a weaker minus spherical for near, maintaining binocular balance there, too. The tide in this country and in Europe was turning back strongly toward Donders' full correction for distance and near, showing indecision and a groping for something more satisfactory in this form of error. Peckham's recognition of the inhibitory value of the base-in prism will stem that tide and place the treatment of myopia upon a more rational basis.

We purpose to carry Peckham's point a step further and ask you to reserve judgment until we can outline the reason for what seems a radical but which in reality is a most conservative and natural step.

Let us take inventory of that which with reasonable assurance we may say one knows about myopia. (1) Not more than five per cent of our new born infants are myopic. (2) Myopia usually develops most markedly between the sixth and sixteenth years. (3) Most cases begin to subside about the twentieth year. (4) If myopia continues to increase after the twentieth year it is probably true and therefore dangerous, progressive myopia. (5) A wide interpupillary distance so frequently accompanies myopia it may be considered a causative factor and especially justifies the treatment here suggested. (6) An elongation of the anterio posterior axis of the eyeball wherein the retina moves from the optical system causes myopia at the rate of three diopters for each millimeter of elongation. (7) Relatively excessive close work tends to increase myopia.

At this point let us venture to establish a more correct classification of uneventful, progressive and malignant myopia. Uniformly throughout the literature, the terms progressive and malignant are employed synonymously. We suggest that cognizance be taken of the fact that this not only causes confusion, but retards and discour-

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ages helpful treatment in some of the most serious but by no means hopeless cases.

Let us agree, therefore, that true malignant myopia be accepted as the result of a pathologic condition and a pathologic condition less likely to be of ocular origin than systemic and one that interferes seriously with metabolism. Ocular treatment alone, optometric or ophthalmologic, will not suffice in such a case and while everything possible should be done from an ocular standpoint, general treatment should not be neglected; in fact, general treatment should take precedence. Such cases are outside the scope of this paper.

And we would eliminate also those myopic cases associated more or less directly with cataract: keratoconus, wherein we find usually a high astigmia with a relatively low myopia; iritis, which often causes temporary myopia of 1. or 2. diopters and which it would be unfortunate to overlook while centering attention on myopia; detachment of the retina; diabetes, whose myopia is usually of sudden onset; luxation of lens wherein the tension of the zonula being removed permits the lens to assume its greatest convexity; or opacities, which necessitate the holding of all near work closer to the eyes than warranted in order to get the help in seeing that larger retinal images afford.

Then let us classify and segregate those cases at the other end which develop myopia early in life but which at or before puberty slow down and remain essentially fixed from there on, always remembering, however, that any case of myopia is potentially a progressive case and worthy of any prophylactic measure we can apply.

This leaves us those progressive myopic cases which while dangerous are still amenable to optometric treatment and not malignant in the sense that back of them stands the menace of a general or local disease.

Such cases we believe may be controlled better than they are being controlled today and that belief is based on the following reasoning:

We find almost universal agreement that the two most important etiologic factors in myopia are: (1) predisposition, and (2) excessive near-point work.

We must accept predisposition or else believe that all school children of today would develop myopia, because of the trying close work demanded from early childhood onward. This we know not to be the case. But given the slightest predisposition we also admit that excessive close work becomes a causative factor because of the lateral pressure of the extrinsic ocular muscles involved in the complex act of converging the eyes to the near working point. Usually only the externi are considered in this connection but we believe the obliques as well as all the recti are tensed in the act of convergenc to a far greater degree than in the act of long-range vision with emmetropic eyes.

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Keeping in mind the divergence of the orbits, the relatively recent acquisition of the ability to converge, the still more recent demands for close application in school and industry made upon immense groups who sprung from agricultural stock amid agricultural environment and it is easy to concede that excessive close work is sure to effect harm in a certain number of cases.

Let us also keep in mind that these demands of school and industrial life will create many cases of progressive myopia of the non-pathologic type, which can be and should be controlled by optometric measures.

To test one's convictions in this matter let him ask himself whether if he had a child of his own showing myopic tendencies, he would not, so far as eyes are concerned, rather see that child living outdoors at long range occupation instead of indoors confined to close application?

No one seriously questions that, but most regret the loss of education involved in pursuing such a course.

The problem is, then, how may we save the eyes in progressive myopic cases and at the same time not sacrifice education?

We offer the following as a solution:

If close work causes progressive myopia in a predisposed case such myopia may be retarded if that close work be done with the visual axis parallel and the extrinsic and intrinsic ocular muscles relaxed as in distance vision and close work may be done under these conditions if from the distance correction 3 D. be deducted and to this approximately 18 base-in prism diopters be added, equally divided between the two eyes.

To apply these principles to cases of progressive myopia all that is required is comfortable means of holding this lens and prism combination in place and sufficiently strict injunction to insure it being worn and the reading matter being held at the proper range. This is what we call a reversed stereoscope.

In extreme cases telescopic spectacles may be used in conjunction with the relaxing plus lenses and plus prisms.

This will be branded radical in many quarters. Well, recall our cases of progressive myopia and a few of those that went blind, which should warrant trying such a method which though seemingly radical in optometric circles is certainly less radical than extraction of the crystalline lens, or tenotomy of the externi! If such radical methods as the latter can be accepted and if after they fail Braille can be learned it seems reasonable and not at all presumptuous in us to urge that we take steps, radical if necessary, of an optometric nature, and at worse far less dangerous, while there is hope left of arresting the progress of the myopia while useful vision remains.

But is this proposed method really radical? We think not. It is not deemed radical to insist on less close work in cases of progressive myopia. But less close work is merely saying more distance use of

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the eye, so if by physical agents we can turn close work into distance work and retain the value of close work, we see nothing radical about doing it and that is essentially what we are proposing.

If it had been practical to print books twenty times the present size and place them twenty times their present distance from the eye their use would have entailed no accommodation and no convergence. This was not practical but with the retinal images the same size in either case the small book if read with a + 3.00 D. Spherical and 9$^{\Delta}$ base-in prism before each eye reproduces essentially the ideal of distance vision.

Now it will be said that by this method convergence will not develop properly. This I do not believe to be so, inasmuch as convergence and its correlated accommodation will develop as well as under outdoor conditions, assuming that these conditions are obtained and besides it may be more important to retard progressive myopia than to develop convergence. At the expense of useful vision is convergence worth much?

Confusion will be avoided if we but keep in mind that this technic is suggested as applicable, chiefly, to those extreme cases where nothing else seems to head off the increase of their myopia.

When the inhibiting value of the *base* of a prism is appreciated, the first step toward the full appreciation of Peckham's work will be taken—and not until then.

With that appreciated it does not seem at all radical to us to use low-power base-in prisms in all cases of myopia, as in all cases of suspected latent hyperopia, and who knows just where the dividing line comes? And after experience with the low-power base-in prisms it does not seem at all radical to us, in dangerously progressive cases wherein the odds are against us anyway to attempt the control of progressive myopia by going a step further and using full-power base-in prisms with equivalent plus spherical power to bring about total inhibition of that muscle action which almost universally is conceded to be the underlying cause of this dreaded condition. Hence, putting it in what may seem a less radical form, we urge that when all else has failed, when the case is about to be considered hopeless, and dismissed to fade away into blindness or at least semi-blindness, dismissed to save our feelings, not to help the patient, just before this is done we urge that full power plus prisms and plus sphericals combined with the patient's correction, be tried. Surely, if all seems lost, this may be tried with propriety.

But look beneath the surface of this timid attitude and note that such is really the radical method because it permits the case to get to almost a totally hopeless state before trying that which may save it and cannot harm it in any event. The truly conservative course and the course which we recommend is to use, part time, these full-power base-in prisms and plus sphericals, this reversed stereoscope as herein outlined, the moment the presence of true progressive

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myopia is established, if not as a prophylactic measure in any case of advancing myopia.

DISCUSSION. Dr. E. LeRoy Ryer brought out the following in the discussion which followed the presentation of his paper. He made it clear first that the entire matter was one in which much research must still be done. In correcting myopia a full correction is permissible for distance but never for near-point work. Base-in prisms should accompany the near-point correction. He repeated the fact that any myopia which increases after the age of 20 is to be considered progressive and measures should be taken to retard the progress of the defect. He also called attention to the five types of pseudo myopia. These being, first, the pseudo myopia of iritis; second, the pseudo myopia of senile cataract; third, the pseudo myopia of diabetes; fourth, the pseudo myopia of the ciliary cramp and, fifth, the pseudo myopia accompanying the extremely large pupil. Following this discussion the Academy adjourned until after luncheon.

The afternoon session convened with Dr. J. H. Drakeford occupying the chair. Dr. Drakeford introduced Dr. E. G. Wiseman.

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THE EVOLUTION OF THE VISUAL APPARATUS

Eugene G. Wiseman, Opt. D., F. A. A. O.
Buffalo, N. Y.

Evolution of the Animal

Most, if not all, animals begin as single cells. Some remain such, as in the case of the amoeba. Others multiply almost endlessly and develop into higher animals.

The unicellular animals—protozoa—are quite as complete units of life as the multicelled—metozoa. The amoeba, for instance, hunts, swallows and digests food and ejects debris. It is quite capable of maintaining its existence under harmonious conditions, and of multiplying its kind.

In some respects, it is even more versatile than more complex animals. It can extend an "arm" or "leg" at will from any part of its "body." It is all eye and all stomach, for example; in fine, it can make nearly any part of its structure perform in any way in which the whole or any other part can perform.

When it desires food, it simply extends itself on either side of the desired particle, thus acting as a mouth, brings the two ends together, thus swallowing, and then proceeds to digest. When this process is completed, it moves on, leaving the debris behind. When desiring to propagate itself, it divides in the middle, and, presto, it has become twins. Another division and it is a family, and so on, ad infinitum. As far as the raw maintenance of life is concerned, higher animals can do no more. They extend their operations and perform more complicated functions but, until very high grades of animal life are reached, there is ground to wonder if the difference is any more than one of magnitude.

Having succeeded with the single cell, Nature moved on to the two-cell, the three-cell and so on to the much higher-celled animals. But soon she had to employ greater ingenuity than in single cell construction. Cells must live, and to live they must have contact with the source of food supply. If cells in a group become too numerous, those inside will be shut off. Of course, it would be possible to extend a string of cells indefinitely, but then its effectiveness would be lessened and its susceptibility to destruction would become greater.

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And so Nature solved the problem by depressing the group in the middle and folding up the sides, thus forming a relatively short tube, and causing the individual cells to take on specialized functions. As cells became buried when the walls of the tube thickened, she built canals (blood vessels) to them and constructed special cells (blood corpuscles) to carry food to them and waste material away from them. Instead of remaining independent units, the cells became interdependent and acted as a whole and for the benefit of the whole.

When the conditions became such that the more complex animal could no longer depend upon the medium in which it lived to bring it food, it became necessary for it to move about more or less actively. To facilitate this, Nature constructed a special group of cells (muscles) having the power of contractility. Those she attached to another special group (bones or shells) and arranged the whole so that the animal could propel its body in the direction of food or away from danger.

In its earliest development, probably the life of the animal was conditioned upon simple chemical action and reaction. It might even be that positive and negative charges of electricity played their part. But in the higher forms, it is evident that complexities developed. It became necessary to convey the chemical and electrical entities from one cell or group of cells to distant cells, and to do this with a minimum loss of potentiality and a minimum disturbance of intermediate cells.

We have mentioned the blood stream as one agent for this purpose. When muscle cells were created it became necessary to invent another conducting system. And so nerves came into being. These carried impulses from one part of the animal to another and caused that other to act for the preservation of the animal as a whole. This implies intelligence—of a kind. We do not mean intelligence as the word is ordinarily used but the sheer physical ability to receive sensations from the external world and interpret them as beneficial or malevolent.

The tube-like animal developed this ability in three areas—the external layer of cells, the internal lining of cells and the intermediate or deep cells. Probably the reactions at first were, as suggested, purely chemical. Later, or perhaps even coincidentally, they became mechanical, and thus, we may say, the sense of contact or touch was started on the way to development.

As the structure became still more complicated, Nature found it still more necessary to do what we humans do when we have a large disorganized body which it is desirable to preserve. She established a center of control—an area which co-ordinated all the impulses received by the body and regulated them so that antagonistic forces would be harmonized and economy of operation would be assured.

This we call the central nervous system. When any part of the animal received an impression, it was sent to the central nervous system for interpretation. If understood to be beneficent, orders were

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sent to a certain group of cells to act in a certain way. If harmful, another group were called upon to respond in the particular way for which they were constructed. Thus the animal was equipped to accept conditions favorable to its existence or reject those unfavorable.

But as the animal grew still further in complexity and as the struggle for existence grew more intense and involved, it was not enough to possess tactile sense. It became necessary to recognize the friend or enemy to its existence before actual contact was established. Hence, special areas of the animal grew in sensibility to external influences.

One developed taste, enabling the animal to select food before taking it into the body. That was only a slight advance over the tactile sense.

Another went farther and recognized minute emanations from the distant object. That constituted the sense of smell, and projected the animal's power of recognition quite a distance beyond the body.

But this was not far enough, and so another group of cells recognized physical vibrations of the medium in which it lived, and thus hearing was born. This extended the field of observation greatly.

Still it was not great enough. Danger could approach silently and the animal be destroyed before it had the slightest opportunity to fight or flee. It became necessary otherwise to be able to recognize friend or enemy.

A special patch of outer cells—skin—became sensitized to light, and thus the first eye was born. This projected the animal's intelligence into a vast area and made it possible to move around more freely and more safely. Enemies could be avoided and food more easily obtained. The continued existence of the animal became assured.

No one can say how much farther the animal may be developed. It may be growing rudimentary cells which will still more greatly augment its power. As we view existence today, it is plausible to surmise that the animal's next sense will enable it to read the minds of others, since the dangers of physical contact are growing less (despite the automobile) and the desirability of anticipating accurately the designs of those inimical to our safety is necessary. However, we have enough, in these lectures, in dealing with the past and present.

Evolution of Man

If we take the liberty of passing over certain stages of existence, we may say that the first man was a fish. It grew an articulated vertebra and possessed the power of relatively rapid motility. To increase its speed it developed fins. It became so highly evolved that it grew dissatisfied with its environment—even as humans do today—and flopped out onto the land. Its fins altered into arms and legs, it walked erect, it climbed trees and now it can perform the most intricate motions with the various members of its body. It even again is becoming dissatisfied with its element and is aspiring to fly. Possibly

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when gliders are developed to the stage where this glorified fish can propel himself in the air from place to place by arm and leg power he will literally conquer the air and not depend upon machinery to do it for him.

The evidence of this development, stage by stage, still exists in the life upon this planet today. Step by step it can be observed. There are fish which flop upon the land and climb trees. The tadpole is almost precisely similar to the spermatozoa of man, and it grows legs and rudimentary arms and becomes a frog. The saurian has four legs and a tail much like a fish. It lives partly in and partly out of the water. There are animals which lay eggs and others that fly. Others possess further evidence of relationship to both fish and fowl and other animals. The chain of evidence from amoeba to man is fairly complete. A missing link here and there does not destroy the clear proof of a connection.

In each step of his growth from one cell to 26 trillion, the varied functions which man has developed have in some cases increased in effectiveness and in others decreased. As his environment has changed, the value of his senses has changed with it. Nature wastes little and seldom maintains two organs when one will serve the purpose.

Hence, as man's intelligence became greater and the power of observation and rapid analysis grew, some of the higher functions seem to have declined. Either that or they did not develop in man as in other animals. For instance, his tactile sense is greatly inferior to some low grade insects. His olfactory acuteness cannot begin to compare with that of some insects and other animals. His acuteness of hearing is very low and his sight is decidedly inferior—apparently both in the visible scale of the spectrum and then of course outside it, for there seem to be eyes which register rays that are absolutely nonexistent to man.

In the first group are the birds which apparently possess vision a hundred times as acute as man's. That explains how vultures, for example, will flock around a dead animal twenty minutes after it has been killed, although the death has occurred miles out in the desert and no vultures have been visible anywhere to the human eye.

In the second group are such insects as mosquitoes to whom the human body is said to glow in the dark like a red hot piece of metal. Perhaps bats come in a somewhat similar category, since they can fly around an absolutely dark cavern and never touch the wall. However, in that case other senses are more likely to be the dominant ones—hearing and smell.

But in one respect man's sensory equipment rises superior to that of all other animals. He normally possesses binocular single vision. His two eyes fix upon the same object at the same time. No other animal possesses this function as a constant, and only the higher apes possess it intermittently. In all others the eyes are fixed alternatively and the fields of vision either do not meet at all or they

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only partially overlap. In man they exactly coincide and form one. This situation constitutes a form of unconscious triangulation and enables man to judge distance more or less accurately without depending entirely upon memory.

Doubtless, in some of the lower animals this function is yet in the process of evolution. Perhaps because of its early growth in man he is today the highest developed animal on earth.

Let us see how this may have come about. When fishes inaugurated the first May day movement, they doubtless were accompanied by other animals. Or some fish were different from others. As they separated and developed along different lines, some varieties of these creatures began to devour other varieties, just as they do today, both on land and in water.

Naturally, the instinct of self preservation asserted itself and the weaker creatures began to cast about for means of preserving themselves. Not being stronger, they had to resort to strategy or flight. Not being fleet enough on the ground, they literally "took to the tall timber" and began to live in trees.

Now it is one thing to climb trees as a diversion or to avoid danger and quite another to live in them constantly. The latter requires great agility and more or less speed.

Even these were not enough, however. Accurate judgment of distance was imperative. It would be fatal to swing from one branch or tree to another and underestimate its distance by a matter of inches, especially if the jaws of a hungry animal were open beneath.

And so Nature constantly pushed the eyes forward until at last their lines of vision intermittently at least met at the object viewed and the animal could calculate accurately the distance of the limb or the cocoanut or any other thing it wanted to grasp.

All of this implies the development of greater intelligence. This animal used its brain to avoid danger and its brain grew as it was used. Very likely the acquisition of stereoscopic vision gave a tremendous impulse to the cerebral cortex, and that particular species of fish-monkey-man rapidly surpassed all others of its cousins. Except in a special sense, it did not necessarily descend from such monkeys as exist today. It *may* have descended from the same kind of *fish* but its tribal life probably was lived apart from its cousins and it certainly surpassed them in its intellectual progress.

With the acquisition of stereoscopic vision, which eventually became an habitual function, it is natural to assume that our monkey-man developed confidence and manual skill and cunning. Eventually he came down from the trees—another man-like evidence of dissatisfaction with environment—and walked the earth, pitting his intelligence against the brute force of his enemies. Today he is master of all and has assured his continued existence to such an extent that he bids fair to over-run the earth and literally devour himself out of house and home.

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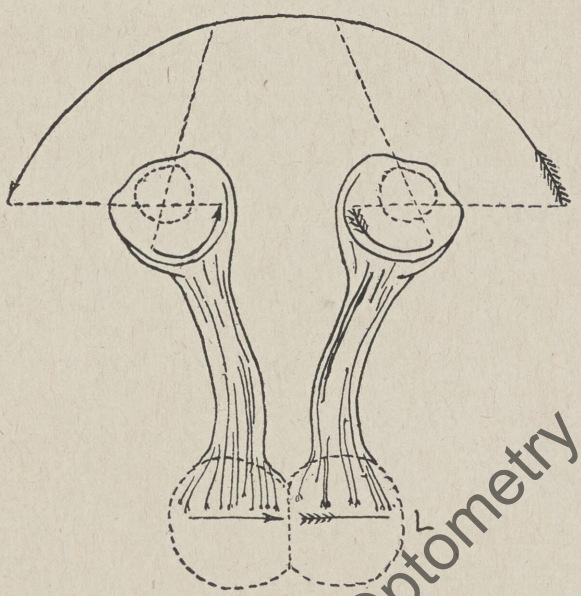

Figure One. Diagram showing the distortion of the mental image of an object in lower vertebrates without an optic chiasm. (Cajal.) L—Visual Center.

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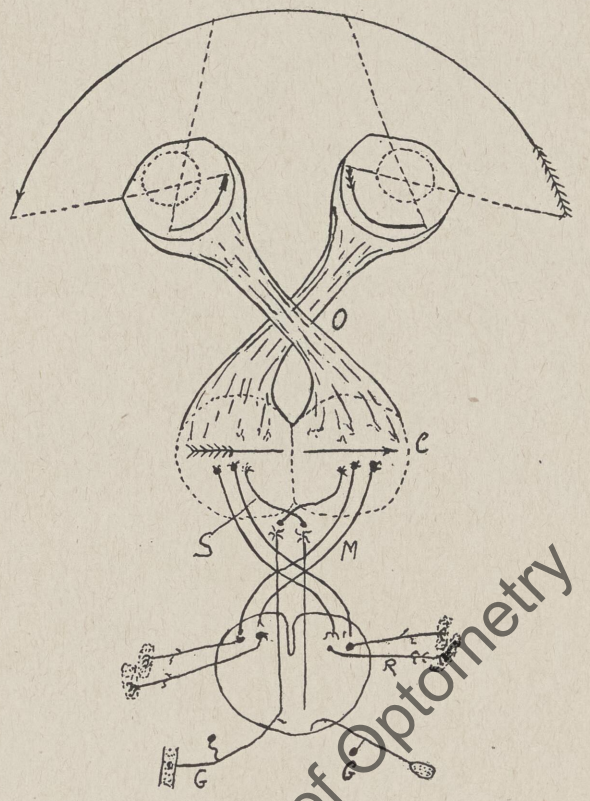

Figure Two.—Diagram showing the usefulness of the optic chiasm and the compensatory decussations of the motor and sensory tracts in the lower vertebrates. (Cajal.) C—Secondary Visual Centers, showing incompleteness of each field. G—Spinal ganglia and sensory roots. M—Crossed motor tract. O—Crossed optic nerves. R—Motor roots of the spinal cord. S—Central termination of crossed sensory tract.

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From all this it seems safe to assume that the dominating factor in man's development from the time he "landed" up to the present was his visual sense and all that involves. It will be interesting and valuable, then, to look more closely into this subject and note just how the organ of vision and its connections have developed.

Evolution of the Visual Apparatus

The first visual organ was a supersensitized patch of skin. Perhaps its first function was to recognize the thermal value of light so that the animal could become conscious of the existence of an object foreign to its environment when the latter came between it and the source of heat. Commonly, there were two of these patches, one on each side of the body, although they possessed great variety and were located in many different places.

Their exposed position permitted injury too easily, so Nature's next step was to sink them into little hollows. That was better, but still sand got into them and spoiled their effectiveness.

Then she covered them over with a jelly-like substance and that again was an advance but it did not keep out the stand. And so she grew a hard, celluloid-like transparent layer—the cornea—over the jelly and at last attained a measure of real protection.

Along with all this there was a simultaneous development of an optic nerve which conveyed information to the central nervous system. This was rudimentary but it served its purpose.

The results of this embryo eye must have been so pleasing that Nature began in earnest to experiment with the construction of a practical seeing organ. The transparent covering she made convex so that the light tended to focus on the nerve endings behind the jelly-like filling. Into the latter she introduced a hardened group of cells which she shaped into a lens and thus doubly insured a focusing apparatus—a compound eye.

Since an eye which rigidly pointed in only one direction necessitated constant movement of the entire head and body, she enclosed it in a tough spherical membrane—the sclerotic coat, freed this from all connections but the optic nerve and permitted it to roll in its socket. So that it might roll deliberately, she attached muscles to it, thus permitting the brain to assume control and point the eye in different directions. That saved the head and body a lot of work.

To the cornea she supplied sensory nerves that the presence of harmful agencies might be known, and over the cornea a curtain—the lid—which could be slid at will—another form of protection. Behind the cornea she placed another curtain—the iris—with a hole in it so that the amount of light penetrating to the now extraordinarily sensitive optic nerve could be regulated.

Basically, this is the eye humans possess today. There are many other varieties, all testifying to Nature's ingenuity in constructing experimental mechanisms. But these we can pass over and concentrate upon the main object of this study.

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The fish was a very useful progenitor of man. From it we get our vertebra, our brain box, our ears, our spinal cord, our cage of bones for the protection of internal organs. Bones that are inside the body instead of outside—shells.

And from it seemingly our eyes. It is a pity we did not inherit also the electric light plant some fishes carry with them—shooting beams out of port holes in their bodies so they can see surrounding conditions. But, the fish cannot build a fire, so perhaps we are even there.

When the fish left the water its eyes began to move forward in the head. We could jump a few million years and state that they continued moving from a position where their axes formed a straight line directly through the head of the fish until they became parallel, as in man, but the evolution of the visual apparatus is too important to pass thus perfunctorily. One eye, yes, but not two.

We may safely suspect that the change from continuous axes *across* the median plane of the animal to parallel axes *along* the median plane, produced profound changes in the entire mechanism. And so it did.

But to understand this thoroughly, let us go back a little farther —to the ancestors of the fish's eyes. Probably the first pair of eyes, located as are the fish's, each had an individual optic nerve leading to the brain on the *same side*. This produced cerebral pictures as illustrated in Fig. 1.

Very likely the right sight center was connected by nerve fibers with motor apparatus on the right side, and so the animal could push itself away from an unfriendly object, observed by the right eye, or pull itself toward a friendly one. It may have possessed the power to suppress the image seen on the other side by the left eye, or at least it exercised some judgment as to its character and permitted dominancy of either image as circumstances dictated.

During the period of development between this ancestor and the fish, the optic nerves *crossed* each other, and thus the right eye was connected with the left half of the brain, and the left eye with the right half. Possibly this was in the interest of self preservation, and had something to do with developing musculature.

The cerebral result of this crossing (decussation) is shown in Fig. 2. Here it will be observed that while the mental image of the vertebrate's environment is reversed and divided, each half bears its proper relationship to the other. As the eyes moved forward, we see by Fig. 3 that the halves are joined and form a continuous image. Thus, without any motion at all the animal could view at once the entire front half of its environment, and probably 50% of that which lay behind. Even now man, with his eyes entirely in front, can see 190% of his surroundings without moving his eyes. He sacrifices most of that which lies behind in order to obtain stereoscopic vision but there is some compensation for this in his very flexible neck

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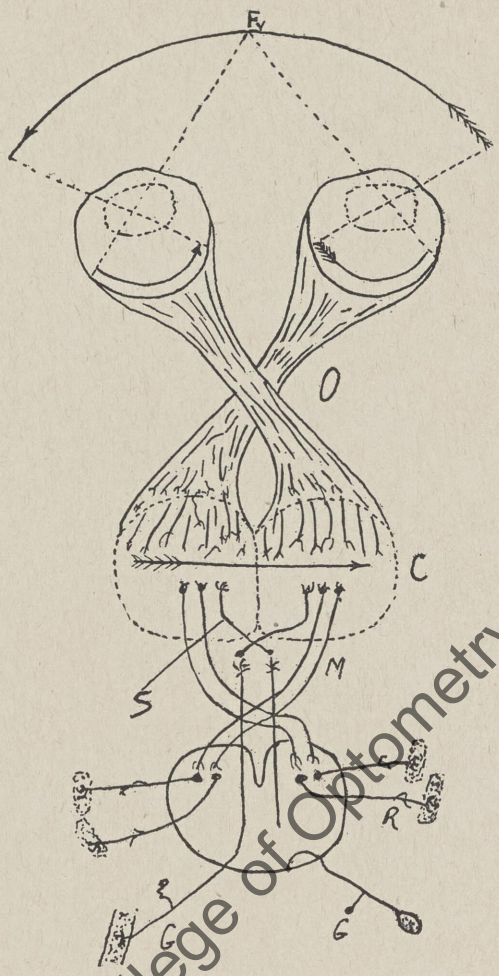

Figure Three. Diagram showing complete fields. C—Shows the completeness of the fields, and Fv showing the common point of meeting of the temporal extremity of each visual field.

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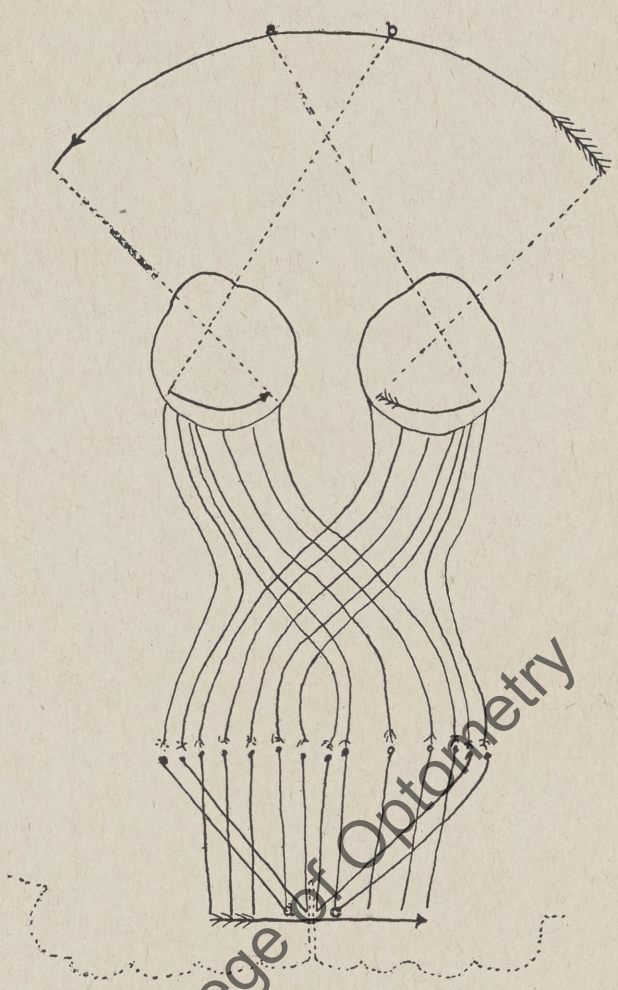

Figure Four. Diagram showing a partial overlapping of the visual fields which necessitated a rearrangement of the decussating nerve fibers. Stereopsis was limited to the area restricted by the extent of the overlapping of the visual fields. a-b, d-c shows stereoscopic area in visual cortex.

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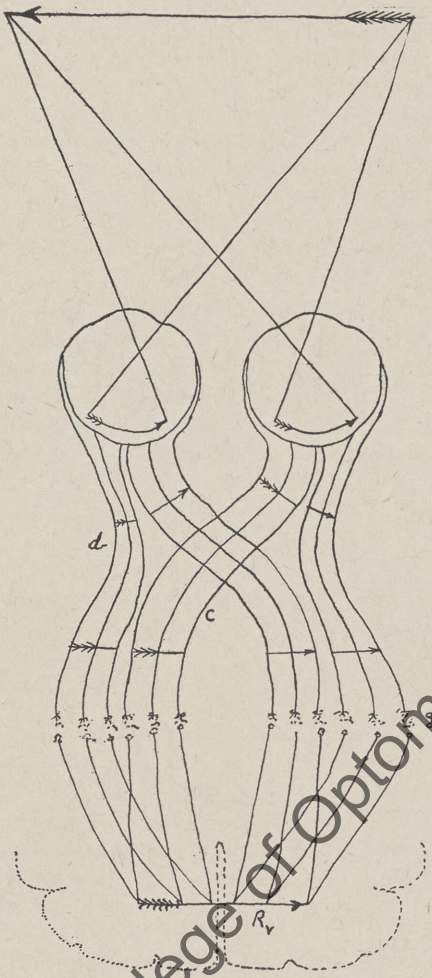

Figure Five. Diagram of the chiasm of the optic tracts and the central projection in man. (Cajal.) c—Crossed fasciculus of the optic nerve. d—External geniculate body. R_v—Projection of the mental image in the visual cortex of the brain.

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which permits wide and rapid excursions to the side. We touch upon this later.

From this point onward the real complications of the nervous system develop. As the eyes moved still farther forward the visual fields overlapped proportionately. Each eye began to get glimpses of the same object simultaneously—indirectly, to be sure, but none the less real. There being no special reason why two portions of the brain should serve the same purpose without added profit, Nature began to split the optic nerve, retaining on the same side of the cerebral cortex those fibers which carried images duplicated by the other eye in the opposite side of the brain. Thus there occurred an overlapping of the fields as seen by the two eyes, as in Fig. 4.

Doubtless this partial overlapping permitted a crude, elementary form of stereopsis to exist, for in certain kinds of defective human eyes where it is obvious that each eye is not fixing the same object at the same time, single vision exists and a measure of stereopsis is demonstrable. This is explained by the ability of the brain often to emphasize or suppress the sensibility of any particular area which might arouse or permit obnoxious disturbances if allowed to function as it normally does.

These ocular defects in man are among the most difficult with which the specialist has to contend, for they have superinduced cortical changes, and thus unconscious habits which have been years in developing must be broken down before the eyes will begin to function as a single unit in a normal manner.

As the two eyes pushed still farther forward, the fields overlapped more and more until finally they precisely coincided and thus stereoscopic vision was born and Nature had achieved her ultimate aim. The optic nerves in man are found to be so divided that the right and left halves of the visual area in the cortex each register the images as seen by the right and left halves of both eyes respectively, as shown in Fig. 5. In the lower vertebrate this beautiful matching does not occur. It not only insures stereoscopic vision but guarantees full, or almost full, front vision if one eye is blinded or if one half of the cerebral cortex is destroyed or even if the optic nerves are severed in the median plane as they join and partially cross. In the latter case each eye still possesses half a field.

Coincident with the growth of this semi-decussation of the optic nerves, almost the entire central nervous system of the animal undergoes similar changes. Groups of muscles must have nervous connections with both halves of the brain and, in a sense, with each other, in order that they can co-operate and harmoniously respond positively or negatively to sensations received by either half of the visual brain. Thus there developed a crossing and re-crossing of nerve fibers in the entire central system and a most extraordinary net work of tracts which we are just beginning to unravel, despite the years which have been devoted to study of them.

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This crossing of fibers has such an important bearing upon our present study that we quote as follows from Tilney and Riley:[1]

"For what purpose or as the result of what causes the great fiber-crossings occur in the neuraxis is not clearly understood. Cajal, however, offers an explanation concerning decussation in general which seems as logical as it is ingenious. All decussations of tracts, according to Cajal's interpretation, depend upon the character of the vertebrate eye. The hemispherical, concave retinae with the biconvex lenses of the eyes make it essential that the optic fibers shall decussate in order that a proper mental perception of external objects may be created. Cajal believes that the crossing of the optic fibers was, in all probability, inaugurated in the fish and cephalopoda. Primitively this decussation was complete and served as the organic means of determining a mental fusion of the separate visual images received by the two eyes. The corrected visual perception could not be created without the existence of a bilateral center in the brain, each half of which co-operated with the other. The optic decussation established the proper relations between these bilateral visual centers and the two eyes. Furthermore, it exerted a decisive influence upon other pathways in the nervous system, consequent upon the reversal of the mental image in the brain. This reversal of the mental image necessitated a compensatory crossing of other tracts, especially in the motor pathway. Such compensatory motor decussation in turn determined a crossing of the sensory tracts. In this manner the character of the vertebrate eye, which in the first instance enforced the complete crossing of the optic fibers, ultimately determined all decussations within the central nervous system."

Influence of Eyes Upon Mind and Health

From all the evidence on hand it is easy to deduce that the growth of the visual system had more to do with the elaboration of the animal's physical state than perhaps any other factor. That it played quite as important a part in its intellectual growth also is perhaps not quite so acutely realized.

Physical areas grow through activity. Physical activity which is based upon deliberate calculation necessarily arouses cerebral processes, which in turn expand and are capable of initiating more elaborate and intricate anatomical movements. Thus there is a complementary development of both areas—the calculating mental and the responding physical, both being also stimulating; hence, the "itch" to perform some kind of work after a period of idleness.

If deliberate and skilled movements require thought, the fact presupposes thought mechanism, and the existence of the latter implies the existence of muscular and nervous mechanisms to carry out the command. Hence all of these are developed more or less simultaneously. After repeated experience, the deliberate factor becomes burdensome to the mind and the process takes place more or less

[1] "The Form and Function of the Central Nervous System."

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automatically—mechanically—subconsciously. This permits the mind to devote itself to other affairs.

The intermediary between primary brain activity and muscle is usually the visual system. The dancer at first looks at his feet, the pianist at his fingers, the writer at his fingers or the end of a pencil. They all get mental images of the act to be performed. These images are retained in the mind even after the act has become so habitual as never again to be thought of.

The mind is largely built up of these images. It has been determined that over 80% of the knowledge which we get we obtain through the eyes. Since we retain the resultant images and since the brain is the physical counterpart of the mind—or the "home" of the mind—it is obvious that as the mind grows, the brain also must grow. If we "create" a new cell for each new image and each new thought, it is obvious that no matter how small the cell, the bulk of the aggregate is bound to grow to considerable proportions. That is why the human brain is larger in proportion to body than most animals. But size does not necessarily mean brain power, for a few creatures—species of birds, monkeys and mice—possess relatively larger brains than man, and often idiots have larger brains than geniuses. The factor of quality enters, and the size of cells, and the use to which cells are put. It is conceivable that brain cells atrophy from non-use and that large areas possessing potential capability are permitted to lie idle, through lack of incentive which stimulates activity. Few if any individuals use their brains 100% and most use their brains to hardly 10% of their thought-capacity.

Those areas of the brain used in the act of vision are numerous and some are large. There are twelve principal cranial nerves and, of these, four are devoted exclusively to the eyes, two others have definite eye associations and a part of the great sympathetic system is directly connected with the eyes. This suggests the relative importance of the visual system to the rest of the body functions with regard to at least the intellectual development of the human animal.

The muscular system of the eyes is, of course, the counterpart of the nervous system. It is said to be the most complicated and delicate in the entire body. There are six muscles which rotate each eye, two which control the iris and one compound muscle which adjusts the focusing apparatus, thus making a total of eighteen for both eyes. These eighteen muscles are called upon to make tens of thousands of instantaneous adjustments each day and these must be made with infinite exactitude. It should not be surprising that when each adjustment is made under stress, as in defective eyes, very real symptoms of discomfort arise. Nor should it occasion wonder that, since the visual system occupies such a tremendously important position, nature will pour into the eyes energy routed from its natural destination in other organs in order to obtain clear and stereoscopic pic-

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tures for the brain, with the result that often these other organs suffer and protest and then manifest the symptoms of local defects.

When normal, the human body begins life as a well balanced mechanism. All organs function smoothly and there are therefore no organic stresses to cause discomfort. But when there is abnormality, upon its extent depends the comfort, health, the sanity, the life of the individual.

Whether or not it is true that few begin life with perfect bodies and functions, it is indubitable that only a small percentage—if indeed any—continue to remain normal very long. If they are physically perfect, they soon introduce into their minds or their bodies disturbing factors—thoughts which disrupt orderly mental processes and often react detrimentally upon such physical activities as digestion and blood flow, and food which, when not primarily poisonous, is chemically split into poisonous elements and injures delicate functional mechanisms. It can even affect the mind itself and may ultimately kill the individual.

It is said that few are born with perfect eyes. Some scientists say that all are hyperopic, though "Fuchs" states that 5% are myopic. The latter condition tends to increase and then decrease in later years, and the former to decrease and then increase. As we shall later point out, some of the theories intended to explain these changes are based upon entirely false premises. They are primarily functional and not anatomical, as has long been thought, with the possible exception of those occurring in the first few years of the individual's life, though there also the factor of function plays its part and modifies anatomical changes.

Aside from mentioning that the newly-born has not complete control over the movements of the eyes and that they therefore fail to co-ordinate until some months have passed, scientists have had little to say about the status of the rotating musculature in the child. The generally accepted fact that it was useless to expect exact measurements until the stereoscopic sense was established discouraged and even rendered useless any attempts at mensuration. And when the fusional sense finally "set," the apparent status of perfect equilibrium was accepted as indicating ideally adjusted and innervated muscles.

It has recently been discovered that this ideal condition is not as common as supposed. If we could take a group of infants and suitably observe for a period of five or ten years their rotary ocular muscles we might be surprised by the results. It is quite possible that these would be found to be defective quite as frequently as the refractive condition—that the condition of apparent orthophoria is usually false—that exophoria is the natural status of the ocular muscles when at complete rest.

We would not be justified in expecting anything else. Binocular single vision is the latest acquirement by the visual apparatus of man. Naturally, it possesses the incompleteness of most new mechanisms. Since it is the last stage in the progress of the eyes from the side to

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the front, it is quite natural that if there is any tendency from parallelism it is toward divergence.

It is not necessary to depend upon reasoning to establish the merit of this idea. Anatomists say all eyes diverge in death. They diverge in sleep. The axes of the orbits diverge. There are more muscles controling convergence than influence divergence. If a pair of eyes are orthophoric, and the muscles are under normal tonus, the removal of this tonus from all muscles will naturally have a greater effect upon the convergence than upon the divergence factor. Consequently the total relaxation will result in the eyes turning out.

Actually, the postulate ceases to be uncertain, in the light of recent investigations, because it is found that a very much higher percentage of eyes do have the divergence tendency than has heretofore been supposed. Indeed, most esophores are found to be exophores, notwithstanding the assertion of the perhaps most eminent investigator of the motor apparatus of the eyes that esophoria is the commonest defect.

Since the desire for stereoscopic vision is the dominant trait of the normal visual mind, it is natural that any tendency of the visual axes away from parallelism will be strongly combated. Rarely the desire for *clear* images overcomes the desire for *single* images, and the eyes converge or diverge to excess but that is not common compared with the determination of the brain to have stereoscopic vision at the expense of clarity.

In combating diplopia, the motor centers of the nerves which control the muscles are called upon for action. There is such an intimate relationship between these centers that activity of one involves activity of another. It so happens that in one instance this co-activity results in increasing one kind of optical defect and decreasing another or even of transforming the latter into the former by the same process. In the early stages, it is possible to reveal the true state of affairs by utilizing suitable appliances but later the visual mechanism becomes "set" and cannot be relaxed.

In consequence of these discoveries, all previous statistics concerning the relative prevalence of various eye defects may be questioned as to their usefulness. So, also, may we question the value of findings in individual cases. In the light of this new knowledge, cases apparently orthophoric are found to be exophoric, those that have been diagnosed as esophoric are orthophoric or exophoric. Myopia and emmetropia are found to be hyperopia, and slight hyperopia is discovered to be higher hyperopia.

This all implies strain. It means far greater strain than has hitherto been suspected. Despite the broadness of the claims concerning the great variety of ills which can arise from eye-strain, the number can still be more greatly increased. At least, the number of individuals affected can be greatly increased, for many who for years have had the very best attention and who thought their eyes were free from strain are now found to be the most severe sufferers from it.

(Adjournment.)

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